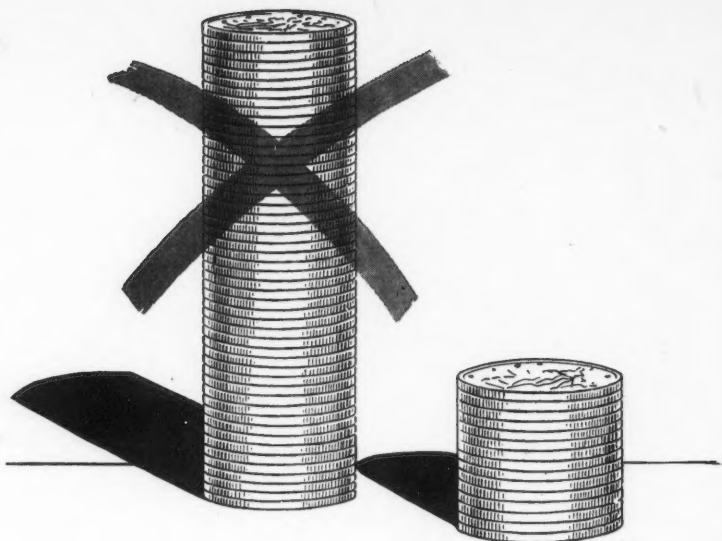


# Corrosion



Oil-Field Tank Corrosion—Page 238



## Reduction in Capital Investment An Important Factor in The Economics of Cathodic Protection

**C**ORROSION-PROOF pipelines are now being built, and built economically by using modern protection systems. Because Coal-tar Enamels provide stable insulation to steel pipe, fewer Cathodic Protection installations are needed, thus reducing the capital investment and requiring a minimum amount of electrical current, maintenance and amortization annually.

With the use of Coal-tar Enamel, applied properly by modern methods of application in the mills or in the field, as

much as 60 per cent, or more, can be saved in the cost of the complementary Cathodic Protection.

Barrett Coal-tar Enamel, which possesses high dielectric strength, provides constant, uniform and long-lasting stable underground insulation, and retains electrical stability over a long period of years and under varying conditions of soil and climate!

The use of Barrett Coal-tar Enamel assures the economy of your investment in Cathodic Protection.

**THE BARRETT DIVISION**  
ALLIED CHEMICAL & DYE CORPORATION  
40 RECTOR STREET, NEW YORK 6, N. Y.

**FIELD SERVICE:** The Barrett Pipeline Service Department and staff of Field Service men are equipped to provide both technical and on-the-job assistance in the use of Barrett Enamel.





## Contents

Maintenance of Oil Field Equipment, By D. R. Hiskey.....	235
Selenium Rectifiers for Cathodic Protection, By W. F. Bonner.....	249
"Thermogalvanic" Corrosion, By N. E. Berry.....	261
Corrosion Criteria—Their Visual Evaluation, By Marc Darrin.....	268
Some Metallurgical Observations with Respect to Corrosion in Distillate Wells, By M. E. Holmberg.....	278
Corrosion—News Section.....	11
Bibliography of Corrosion Testing Methods, 1935-1945, By Lorraine R. Voigt.....	16
Corrosion Abstracts .....	30

Reproduction of the contents, either as a whole or in part, is forbidden unless specific permission has been obtained from the Editor of Corrosion. Articles presented represent the opinions of their authors, and not necessarily those of the Editors of Corrosion or the officers or members of the National Association of Corrosion Engineers.

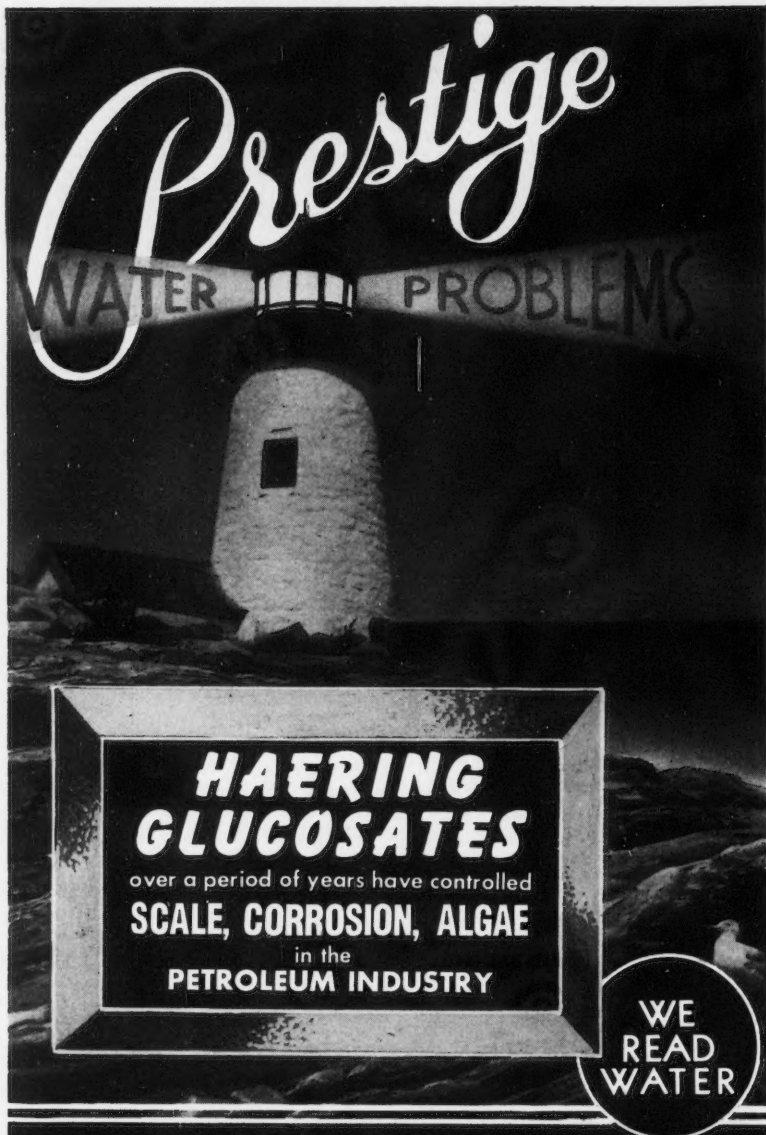
EDITOR, Dr. Ivy M. Parker

MANAGING EDITOR, William J. Sagstetter

EXECUTIVE SECRETARY and ADVERTISING MANAGER, A. B. Campbell

Subscription: \$3.00 per year to non-members. \$2.00 of member's dues are applied as subscription to CORROSION. Additional single copies to members 50 cents, to non-members 75 cents. Publication office, 905 Southern Standard Building, Houston 2, Texas

Copyright, 1946, by The National Association of Corrosion Engineers.



*Prestige*

WATER PROBLEMS

**HAERING  
GLUCOSATES**  
over a period of years have controlled  
**SCALE, CORROSION, ALGAE**  
in the  
**PETROLEUM INDUSTRY**

WE  
READ  
WATER

**D. W. HAERING & CO., Inc.**

GENERAL OFFICES:

205 West Wacker Drive, Chicago 6, Illinois





Pipe Cleaning, Coating and Wrapping  
to any coating and wrapping specification

**Complete Reconditioning  
Service for Old Pipe**

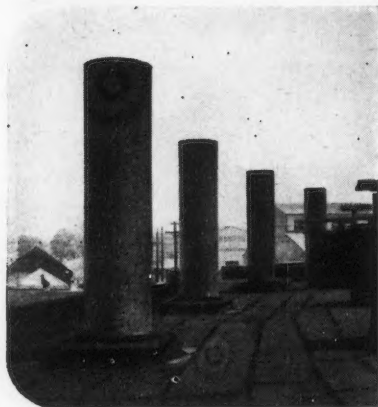
**mb MAYES BROS., INC.**

HOUSTON, TEXAS

# BITUMASTIC

REG. U. S. PAT. OFF.

## Protection



Bitumastic Hi-Heat Gray, applied to stacks subject to temperatures as high as 1200°F., gives dependable protection from atmospheric corrosion and combustion fumes.

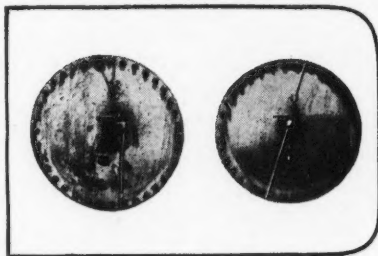
### FOR STACKS AND BREECHINGS

Rain, sunlight, combustion fumes and high temperatures make the protection of stacks, breechings and furnace doors almost a continuous job when ordinary paints are used. This expensive and time-consuming maintenance work can be minimized with Bitumastic Hi-Heat Gray. The high temperatures, which accelerate the deterioration of ordinary coatings, promote a fusing effect of the metallic zinc powder in Hi-Heat Gray, forming an ever stronger bond with the metal surface. Even after the vehicle has burned away, Bitumastic Hi-Heat Gray assures dependable protection at temperatures as high as 1200°F.

### EXACTING TEST PROVES IT BEST

The accompanying photographs reveal how Bitumastic Hi-Heat Gray resists the aggressive combination of high temperatures, atmospheric corrosion and corrosive still contents which make short work of other paints. Two still doors were coated—one with a good grade of aluminum paint, the other with Hi-Heat Gray—and left for 8 months exposed to the action of fumes at temperatures up to 800°F. Bitumastic Hi-Heat Gray continued to give full protection, while the aluminum paint deteriorated badly.

Contact your nearest Bitumastic Distributor for superior protection in the form of Bitumastic Black Solution, Bitumastic Super-Service Black, Bitumastic No. 50, Bitumastic Tank Solution, Bitumastic Hi-Heat Gray and Bituplastic.



Exposed on industrial still doors for 8 months at temperatures up to 800°F., a good grade of aluminum paint deteriorated badly, while Bitumastic Hi-Heat Gray continued to give excellent protection.

### Wailes Dove-Hermiston Corporation

A SUBSIDIARY OF KOPPERS COMPANY, INC.

WESTFIELD NEW JERSEY

NEW YORK 4

PHILADELPHIA 8

MIAMI 36

CLEVELAND 14

SAN FRANCISCO 10

CHICAGO 3

LOS ANGELES 1

HOUSTON 2

TULSA 3





### Just off the press!

Write for your copy of the new, illustrated booklet describing Fiberglas Underground Pipe Wrap and its application. A copy should be in the hands of everyone concerned with corrosion problems.

It tells why Fiberglas Pipe Wrap helps give better, more economical protection and longer life for underground pipe—why more and more engineers prefer it—and how it is being used.

Fiberglas Underground Pipe Wrap may help you solve present or future problems. Get the facts about it. Write for your copy of the new booklet today. Owens-Corning Fiberglas Corporation, Department 958, Toledo, Ohio. Branches in principal cities.

*In Canada, Fiberglas Canada Ltd.,  
Toronto, Ontario.*

OWENS-CORNING  
**FIBERGLAS**

**BEAT**

# Soil Corrosion



*This machine, especially developed for J-M by Crutcher-Rolfs-Cummings of Houston, double coats and double wraps in one operation.*

## in ONE operation with this Johns-Manville Machine

**A**S fast as pipelines can be assembled, the Johns-Manville machine pictured here applies *double* protection against soil corrosion. TWO coats of enamel . . . TWO layers of J-M Asbestos Felts . . . go on in ONE single operation.

That means installation savings. And these savings continue through years of service because

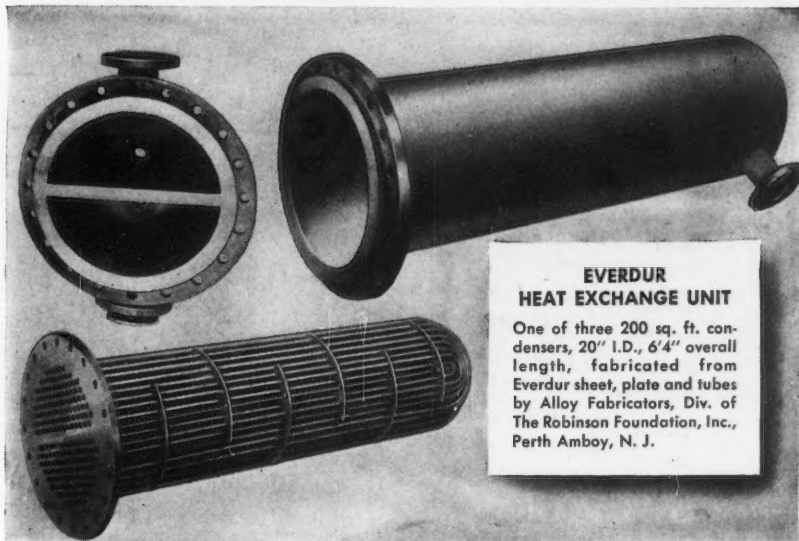
Johns-Manville Pipeline Felts are made of time-defying, rotproof asbestos fibers. It is today the most widely used material for guarding the enamel against soil stresses and distortion.

For complete information, write Johns-Manville, Box 290, New York 16, New York.



## Johns-Manville ASBESTOS Pipeline Felts

# Built of Everdur... to withstand ***HOT CORROSIVE VAPORS***



## EVERDUR HEAT EXCHANGE UNIT

One of three 200 sq. ft. condensers, 20" I.D., 6'4" overall length, fabricated from Everdur sheet, plate and tubes by Alloy Fabricators, Div. of The Robinson Foundation, Inc., Perth Amboy, N. J.

This two-pass heat exchange unit is a good example of thorough workmanship and sturdy, corrosion-resistant construction of Everdur®. Used for condensing hot vapors in the manufacture of synthetic rubber, it is one of three such units built by Alloy Fabricators, Div. of The Robinson Foundation, Inc., Perth Amboy, N. J.

The shell and removable head were formed from 3/16" thick Everdur sheet. The shell was carbon-arc welded with rods of Everdur 1010. Everdur plate 7/8" thick was used for the tube sheet, the tubes being 3/4" by .065" gage Everdur.

This same tough, corrosion-resistant copper-silicon alloy was also employed

for the baffle plates, and for pipe connections on shell and head.

For condenser tubes and other parts of heat exchange equipment subjected to heat and corrosion, Everdur Metal is but one of a number of Anaconda Copper-base Alloys which provide long, economical service under widely varying conditions. For detailed information, write for Publication B-2.

®Reg. U. S. Pat. Off. 45123 A

## THE AMERICAN BRASS COMPANY

General Offices: Waterbury 88, Conn.

Subsidiary of Anaconda Copper Mining Co.

In Canada: ANACONDA AMERICAN BRASS LTD.,  
New Toronto, Ontario



# *Everdur Copper-Silicon Alloy*

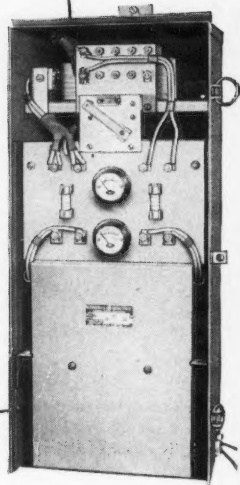
# CORROSION CONTROL

**With G-E Copper-oxide Rectifiers Means**  
*Efficiency... Economy... Endurance*

*here's  
why -*

- ▷ double wall construction prevents direct internal absorption of the sun's heat.
- ▷ bottom location of air-intake and exhaust helps to make casings weathertight.
- ▷ exhaust downdraft keeps intake screen free from insects and moisture penetration.
- ▷ fan-cooled construction on some models permits smaller size and weight for a given rating and lowers the cost per watt-output.
- ▷ units fitted compactly into tall narrow casings facilitate pole mounting.

INTERMEDIATE SIZE UNIT



## THERE IS A COMPLETE LINE TO CHOOSE FROM

The G-E line of fan-cooled copper-oxide rectifiers for cathodic protection has been developed through years of actual field experience. Today—the complete G-E line is providing economical corrosion control safely, and without interruptions even under the most adverse conditions.

For complete information on G-E Copper-oxide Rectifiers, write to Section A34-1183, Appliance and Merchandise Department, General Electric Co., Bridgeport 2, Conn.

**GENERAL  ELECTRIC**



## Maintenance of Oil Field Equipment

*By D. R. Hiskey*

*Dearborn Chemical Company, Los Angeles, California*

**T**HE SUDDEN CESSATION of hostilities of World War II brought industry face to face with the fact that conversion to peacetime operation must be accomplished at a rapid rate. Industrial management faced many problems which could not be worked out overnight. The high speed at which industry had been working since Pearl Harbor necessitated using every resource to produce materials for war purposes. Consequently, many jobs were left undone; much equipment was not properly taken care of because of insufficient labor and lack of time, and, in some instances, lack of proper materials.

Now that reconversion is well under way in most sections of the country, industry is in a position to turn its attention to those jobs which were of necessity neglected during the war years. All of us will agree, I believe, that maintenance of equipment was one problem with which the plant operator was confronted. Because of his inability to secure priorities of sufficiently high rating for materials, the operator was forced to let his equipment stand unprotected. Because of the long duration of the war, operators are now having to spend large sums of money to recondition this equipment.

It is the primary purpose of this paper to deal with some of the new materials which have been developed as a result of research carried

on during the war. Many new materials are now on the market, some which have been thoroughly tested in certain war zones. They will find a wide application in the industrial field. Another subject to be discussed will be the old story of proper preparation of metal surfaces before the application of any type of protective coating, and a discussion of the various types of metal primers.

In the past five years I have traveled over a great portion of the United States and observed metal structures of various types exposed to all kinds of atmospheric conditions. This paper deals with oil field equipment, but it is appalling to see the amount of metal in other industries which has had no protection for years. Most companies and corporations now have definite reconditioning programs worked out, and are resuming much of the maintenance work which has been neglected. It has been my good fortune to secure some very excellent photographs of oil field equipment, some of which will be used in this paper to illustrate the more important points under discussion.

Many papers have been written on the corrosion of refinery equipment and methods of combating it, but very little has been published on field equipment corrosion. Field equipment is just as important to the oil operator as refinery equipment and must be maintained in just

as good condition if successful operation is desired.

I should like to present for your consideration and discussion information that should help solve some of your maintenance problems.

Ferrous metals will form rust in the presence of water, either in the liquid or vapor phase. This observable fact or phenomenon is known to chemists, engineers, manufacturers and industrialists, and has been proved to be electrochemical in nature.

Two of the most important factors accountable for the rusting of iron are moisture and oxygen. There are, of course, other factors which are contributory to corrosion. Such factors can be considered as special cases, and will be treated as such in other sections of this paper, and, in some instances, will require different methods of treatment. However, if either factor, oxygen or moisture, or both, be controlled, then corrosion can be defeated. It has been conservatively estimated that metals worth millions of dollars are being destroyed every year because of corrosion, with a tremendous loss to industry in equipment, time, labor and money. Much of this metal loss can be prevented if a program of equipment maintenance is developed and adhered to, and if proper materials be secured and properly applied.

Only within the last decade have engineers considered the corrosion of iron to be a great menace, and started taking steps to prevent this pernicious evil. To accomplish their purpose, engineers have turned to research, not only in the chemical field, but in the mechanical and metallurgical fields as well.

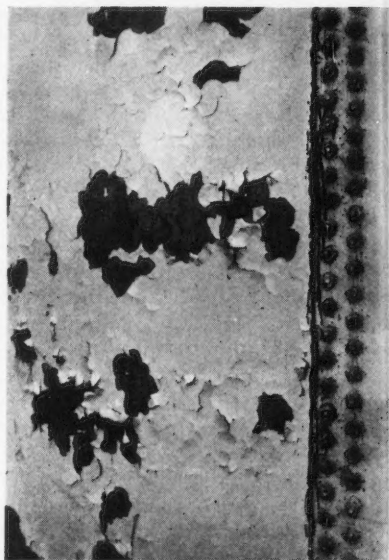


Figure 1—Primer and aluminum coating over mill scale. Coating did not bond to original metal.

New alloys have been developed and are being used in some types of refinery equipment where extremely corrosive conditions occur, and where the commonly known types of corrosion-preventives are not satisfactory. Other alloys have been tested where conditions are less severe. In many instances, these have been satisfactory, but the cost is prohibitive. The alternative is to use the common types of fabricating materials and to protect these from the corroding elements. It becomes a matter of studying the individual operator's problems, and from an engineering standpoint selecting the proper type of protective coatings.

Manufacturers of protective coatings have realized the necessity and value of research, and have spent large sums of money in developing

new products which can be easily and economically applied.

There are today many types of materials which have been used successfully for the prevention of rust. However, with the passing of time, new problems have presented themselves in which many of the older types of materials are not applicable. It is because of these conditions that coating manufacturers have devoted much time and money in formulating new materials.

On any type of new construction, no matter where the equipment is to be installed, as much attention should be given to the selection of protective coatings as to any other part of the job. In the old days, it was a question of applying some material which would cover up the existing rust, and then letting the operating division worry about the maintenance from there on. Times have changed. Operators are becoming coating conscious, with the result that rust preventives applied at the time of installation are designed to give many years of protection, and maintenance can be cut to a minimum.

In the selection of a protective coating, several factors must be considered. These factors have been mentioned and discussed many times, but too much emphasis cannot be placed on them.

It is very easy to select some material which,

because of price, has appealed to the purchaser. Too many times price or cost has been the controlling factor, in place of performance or protection received. The cheapest is not always the best, economically or otherwise.

It is because of this fact that many large corporations, in cooperation with each other or with other agencies, have prepared programs for testing various types of protective coatings, and are making a scientific study to determine which materials give the proper protection with minimum cost.

An ideal coating is one which will do certain necessary things, and have certain essential physical and



Figure 2—Protective coating applied over rust which had not been properly removed before painting.

chemical properties. It is recognized by chemists and engineers that a coating first must bond to the metal to which it is applied; second, it must be impervious to moisture to remain so indefinitely; third, it must be plastic in nature, to conform to irregularities on the metal surfaces, and be capable of maintaining that intimate contact with the metal; fourth, a coating should have incorporated in it a chemical rust inhibitor which will be held at all times on the metal surface; fifth, it must be easily and economically applied.

It is my purpose to discuss each of these five factors in detail, and in so doing, to try to bring to the attention of the engineers and operators reasons why so many failures have occurred in protecting all kinds of equipment, particularly oil field equipment. It is also the purpose of this paper to bring the operators and manufacturers to a closer understanding of each other's problems, and to enable the manufacturers to give oil men materials which will not only solve their problems, but which also have been designed along engineering principles and will give the protection equipment needs.

Discussing our first factor (a coating must bond to the metal to which it is applied), what do we mean by the term, "bond"? In the layman's

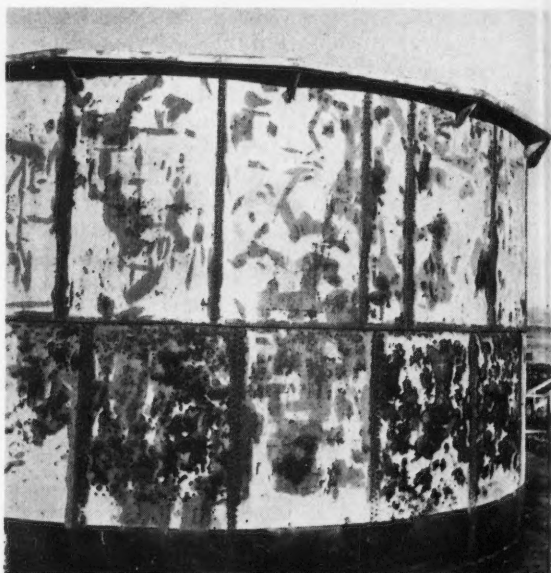


Figure 3—An example of coating over improperly cleaned metal. Places where coating has been retouched show evidence of rust breaking through.

language, we refer to it as anything that binds to, fastens to, or adheres to. Probably one of the best definitions of bond is given by Eric Larson (1), as follows:

"A bond from a corrosion protection viewpoint is the tenacity or power with which a coating grips or adheres to the object covered, or the power to resist complete displacement by physical forces, which displacement would expose the metal. It is necessary to distinguish between the various characteristics which make it difficult to separate a coating from the object coated, and a bond which may have less physical strength to resist displacement, but which provides better protection through a continuous and uniform adherence between the two materials."

Nov

W  
is p  
is c  
is, i  
sible  
prote  
the s  
be a  
wou  
tion  
clean  
failu  
appl  
Ther  
arati  
appl  
Th  
the  
Each  
used  
used  
mech



Figure  
film.  
creas

While on the subject of bond, it is proper to inject a subject which is closely related to bonding, and is, in a more or less degree, responsible for the success or failure of protective coatings. The condition of the surface to which a material is to be applied is important. No one would consider making an application to a metal surface that was not cleaned. Probably 95 percent of all failures can be attributed to faulty application over dirty surfaces. Therefore, let us consider the preparation of the metal surface prior to applying the protective coating.

There are several ways in which the metal surface may be prepared. Each has been tried and successfully used. Probably the most commonly used method is wire brushing, either mechanically or hand powered. The

mechanical method is satisfactory, and probably the cheapest. It is true that this method removes only the loose rust and mill scale and other foreign matter, and does not get down to the bare metal. It is contended by some people that mechanical brushes have a tendency to produce a polished surface, which is not in many instances completely satisfactory and does not produce a good bond between the metal and the coating; however, the mechanical brushing method has proved satisfactory and has produced excellent results.

Other methods of cleaning are sand or shot blasting, acid pickling, and flame cleaning. Sand blasting is probably the next most popular, and it does produce a surface which is ideal for making an application of a protective coating. Wet sand blasting, to which chromate and a mild alkali, such as soda ash, are added to prevent surface rusting, can be used. This method is used rather extensively in the shipbuilding trade. Steel shot, in place of sand, produce just as good results, and some people prefer it over sand because of the silica dust which adheres to the surface of the metal. It is necessary in either case to be certain that the metal surface is wiped free from all dust.

The newest method is the flame cleaning, or priming, method. It consists of a specially designed oxy-acetylene torch where temperatures of 6200° F. are obtained. This intense flame dehydrates the rust and scale, and it is readily loosened and flies away. Generally, light wire brushing follows this operation to remove dust. If at all possible, the primer or other protective coating



Figure 4—Moisture penetrated this paint film. Bond being destroyed over an increasing area as noted to left of bolts.



should follow immediately, as the warm metal surface is ideal for coating. It is claimed by some engineers that the cost of flame cleaning is slightly cheaper than sand or shot blasting. I have seen an accumulation of rust nearly  $\frac{1}{4}$ -inch in thickness removed from the inside of steel water tanks by this method.

Foreign substances must be removed from a metallic surface before any protective coating can be applied. It is useless and wasteful to make such applications without cleaning the surface to be treated, and many protective coatings have been condemned as failures because of such practices. A very striking example is shown in Figure 1. The primer and aluminum coating applied to this field storage tank is peeling off after less than one year,

because of failure to remove the original mill scale from the side sheets after the tank was erected. Figures 2 and 3 further illustrate what happens when coatings are applied over a rusty, scaly surface. No penetration was made into the base metal surface, consequently no bond. Moisture was absorbed, and the coating soon fell away.

Before taking up the next factor in our discussion of an ideal coating, it is essential to mention material closely related to bonding, clean metal surfaces and the final coating; namely, primers. The use of primers is generally two-fold. First, a primer serves as a temporary protection for the metal after fabrication, or during shipment, until it is permanently installed; second, a primer acts as an intermediate coating or

binding medium between the metal and final coating. Mr. Larson (1) further emphasizes this as follows: "The definition states that the purpose of a primer is to act as a bonding agent. Practical considerations have necessitated the extension of the purpose, so that the primer acts as a temporary preventive of atmospheric corrosion . . . The use of a primer as a temporary preventive of atmospheric corrosion presents many disadvantages . . . and this practice has been a frequent cause of protection failure, usually

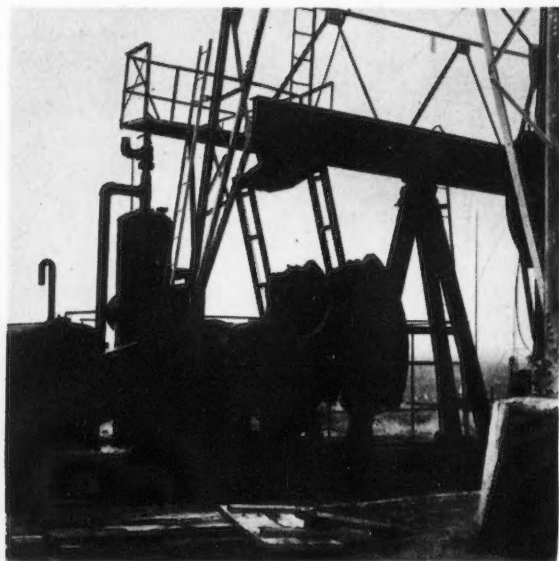


Figure 5—Pumping rigs are difficult to keep properly protected because of constant oil film present. This rig is coated with oil-proof plastic coating and presents clean appearance.



improperly attributed to the materials."

Mr. Larson further states: "The bonding of a primer to the coating depends upon the degree to which the primer is absorbed by the coating. A bond of the surfaces of primer and coating does not provide sufficient adhesion, and, therefore, is to be avoided. The proper blending of the two materials depends upon the ingredients, temperature, state of primer surface, age of primer, and method of application."<sup>1</sup>

Considerable attention should be paid to the selection of primers, and Mr. Larson has very ably stated the facts when he says, "A bond of the surfaces and primer and coating does not provide sufficient adhesion . . . and the proper blending of the two materials depends upon the ingredients, etc." In other words, two materials should not be applied which are not compatible. There should be more than just a mere surface bond, and the outer coating should absorb the under coating.

Our second factor is: A coating must be impervious to moisture and remain so indefinitely. Probably one of the most important points to work from is the base material. Manufacturers are aware of this and have continued research along these lines for many years. In formulating compounds, one base may be satisfactory for one purpose or application and still be unsatisfactory for some other purpose. Therefore, it is becoming necessary to design or formulate coatings for some specific type of application. One type of material is not satisfactory for every kind of corrosion problem, or a cure-all.

It would seem logical to select a

material whose base is not only compatible with a primer, but has low water absorption properties, and contains very small percentages of unsaturated hydrocarbon compounds, so that oxidation due to atmospheric exposure be reduced to an absolute minimum. The material should not be affected by acid or other corrosive gases or liquids. All of these conditions have a relationship to moisture absorption. Only deterioration of the film caused by external and internal conditions will cause failure. The film breakdown permits moisture to penetrate and work in under the film, and, as a result, the bond is destroyed. See Figure 4.

There are many methods by which a protective coating may be tested for water absorption. Many large corporations having laboratory facilities have developed methods for making these tests. These various test-methods evaluate the water absorption qualities in different terms or values, but the over-all efficiency shows close correlation, irrespective of the method used.

Many new materials have been developed as a result of research during the war, where the exclusion of moisture was of major importance, and these same materials are now available for industry. A further discussion of some of these new materials will be made in a later section of this paper.

Coating manufacturers are endeavoring to work in close harmony with the oil industry, and to furnish materials designed for some specific purpose.

Probably one of the most important requisites for an ideal coating, and our third factor for consideration, is that the coating must be

plastic in nature to conform to irregularities of the metal surfaces and to be capable of maintaining that intimate contact with the metal. By using the term "plastic" in this connection, I refer to consistency, and not to the new plastic compounds now on the market. Henceforth, the term "consistency" will be used, because reference will be made later to plastic base materials.

In certain types of oil field equipment, such as tanks, particularly water tanks, brine tanks, and any equipment subject to exposure to considerable moisture, companies have resorted to the use of hot applied bitumens which set up very quickly, and are extremely brittle. Inasmuch as these types of materials set quickly, the filling of pits and irregularities on metallic surfaces is next to impossible. Brittleness in protective coatings is detrimental because shock will cause cracking, through which water permeates. As soon as moisture comes in contact with the metal protected, it loosens the bond, and by capillary action creeps in under the coating, destroying the bond over an ever-increasing area. Breaks in the coating set up local areas where chemical action concentrates, thereby accelerating corrosive action and pitting. Many bituminous coatings do not contain rust inhibitors, thereby limiting the value of this type of coating as a protective medium. Many bituminous coatings are subject to rapid oxidation. This should not necessarily be construed to mean that bituminous coatings have not been satisfactory, but we can assume that these types of coatings have limited application in this field.

Let us retrace our steps and visu-

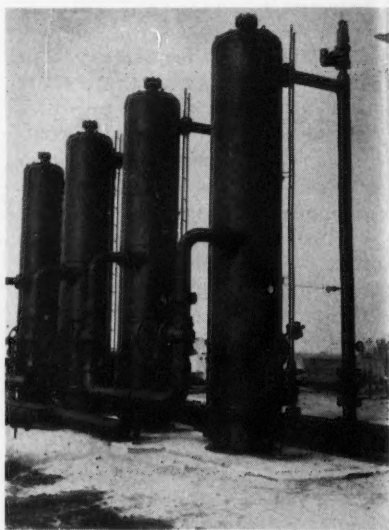


Figure 6—Gas and oil traps are subject to oil films. Properly coated with oil proof plastic coatings they remain protected indefinitely.

alize what is meant by a protective coating whose consistency, shall we say, is softer than most bituminous type materials of the hot applied kind. With the exception of cut-back materials, the bituminous materials are of the enamel type, have softening points around 200° F. and low penetration values. Because of these characteristics, it becomes necessary to heat these materials to at least 400° F., and, in some cases higher, to make the application. As a result, when the hot material comes in contact with the cold metal, it chills and sets immediately. It is true that the metal does absorb some of the heat, but has a good bond been secured? Has enough of the primer been absorbed by the outer material to give the desired results?

Now let us look at it from a dif-

ferent angle. If we are coating metal which has become rusty and pitted, our purpose is to fill the pits with the protective coating to stop any further action. Due to the rapid setting of our hot bituminous materials, sufficient material cannot fill the pits before the coating sets up. I have seen numerous jobs where pitted areas have not been completely filled in; and, as a result, corrosion has continued its attack in those pits.

It was my privilege recently to inspect the inside of a brine tank which was originally coated about two years ago with a bituminous material and guaranteed for five years. During the second year it was recoated six times. The superintendent of this plant stated the material was too brittle and had not formed the proper bond. The point in question is this—a softer, more flexible material would have been more successful. Stating it another way, a less brittle material would have made more intimate contact with the metal surface. After all, the primary purpose is to wet the surface and keep it in that state. This can be accomplished in several ways, with lower softening points, increased viscosities, and delayed setting action. This allows the material to fill in voids or pits before setting and to wet thoroughly the material.



Figure 7—Tanks, tank tops, dampers, and ladders should be maintained properly. Lack of precautionary measures results in conditions illustrated above. The conditions also present accident hazards which cannot be overlooked.

Other materials are on the market which are cold applied, but of such consistency as to allow for film thickness which gives perfect protection. Some are filled to increase consistency, while others are not. They are of such nature that, during application over properly cleaned surfaces, the metal can be wet thoroughly, making very intimate contact and being capable of remaining so indefinitely. Others, while hot applied, have lower softening points, higher penetrations, high viscosities, and, further, due to the higher viscosities, the setting action is delayed.

After all, the purpose of any protective coating is to cover the metal thoroughly with a material which

will remain in contact indefinitely. One reason why the grease or oil type protective coatings have proved successful is because of the difficulty of exposing the metal by such physical forces as shear, tension, and compression. These coatings form intimate contact between the coating and the metal, and remain so. This has been very definitely shown to be true during this last war in the application of rust preventives to war materials and supplies for overseas shipment.

Much has been said lately relative to rust inhibitors in protective coatings, which brings us to the point that an ideal coating should carry a rust inhibitor. Let me repeat that during this last war, rust preventive compounds carrying rust inhibitors were far superior to those which did not carry them. Primers, as well as finish coatings, should carry inhibitors. For many years, red lead has been considered the ideal primer, especially in the steel industry. It is claimed that the action between the red lead and certain fatty acids in the carrying vehicle forms metallic soaps, which have an inhibitive effect on the prevention of rust. There has been much discussion of late regarding this action, and it is contended that the inhibitive qualities are not there. Certain compounds of chromium have been incorporated in primers and other coatings which have proved very successful.

In the recent shipbuilding program, chromate primers were used exclusively on ship hulls and other places, and we need only take a look at the ships arriving at our ports to see how ineffective these primers have been. Chromates, to be effective, should be in a water-solu-

ble form and remain so. They should be thoroughly mixed and in contact with the metal to prove satisfactory. Many chromate primers have carrying vehicles which are composed of synthetic resin bases. These have proved successful as carrying vehicles in some instances, but even these do not always stand up under long exposure to salt water or other corrosive liquids. Some primers, because of the base resins, form brittle films, easily crack and check for lack of proper plasticizers. After all, a primer, even though tough when set, should be flexible enough to withstand normal expansion and contraction.

The same fundamental principles apply to finish coats as well. Inhibitors have a function to perform; they must be present at the metal surface at all times to render inactive any moisture which might penetrate the film because of mechanical failure, or failures caused by de-



Figure 8—Bolt ends and square nuts badly corroded. Particular attention should be given such cases. Metal under stress, under certain conditions, corrodes very rapidly. Neglect is not only expensive but hazardous.

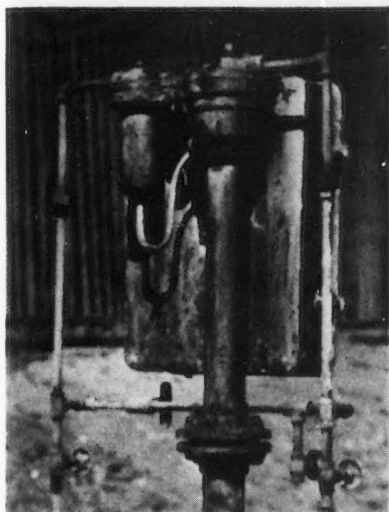


Figure 9—Recording equipment housed in aluminum, zinc, or other metallic cases, must be properly protected when exposed to extremely corrosive atmospheres. Because some of these cases are non-ferrous they corrode at a very rapid rate. Plastic base coatings are satisfactory for protecting this type of equipment.

terioration of the outer film. Therefore, the selection of the primer and final coating which contain the proper chemical inhibitors is important in order that proper protection be maintained at all times.

We come to the question of application. Application of any protective coating has been a problem in many industries. True, most industrial paints can be applied easily by hand brushing or spraying; however, industrial paints are not a cure-all, and have limitations in application. Local conditions have a direct bearing on the type of material to be used. In some cases, hot applied coatings are preferred; in others, the soft grease type; and in the case of the latter two, difficulty has been

experienced with application. Today, however, there is available equipment whereby the hot coatings and grease type materials can be sprayed on the metal in the same manner as ordinary cold applied coatings, and with the same ease. Some equipment is not of special make or build, but can be purchased on the open market at very reasonable cost.

Manufacturers have realized their lack of equipment to make proper applications, and have spent a great deal of time in developing this equipment, so that coating application can be carried on with a limited amount of skilled labor and considerably less time to make the application. With this equipment in operation, a very excellent job of application can be secured, which requires practically no touching up. Hot materials reach the metal surface in a molten condition, with very little loss of heat; and because of the pressure used, a good, secure bond is obtained.

Because of their interest in application methods, coating manufacturers have now a much greater variety of materials to offer to the oil industry, and have taken steps to develop equipment for easy and economical application of protective coatings.

There are special jobs which require special protective coatings; and if the oil operators or superintendents will make separate studies of these jobs, submitting the studies to the coating manufacturers, materials may be available which will be satisfactory.

I should like to mention some of the new, more recent developments in protective coatings. I refer to plastic base materials. We are all familiar with the new plastic materials now appearing on the markets,



fabricated into all kinds of products. Great strides were made in the developing of the plastic industry because of research work carried on during the recent war. Many plastic base materials were used for numerous purposes, and a large amount of data has been secured on performance under all kinds of weather conditions. Nose sections of bombers were made of these materials, as were insulating tubing for electrical cables, coverings for airplane wings, coatings for ships' hulls, and numerous other items.

Because of the work carried on by private corporations, military personnel, and educational institutions, protective coatings have been made which have a wide application in all branches of industry. Hot-applied coatings for the preservation of precision tools and parts is one phase of the work accomplished. A tool is coated and stored. When the tool is needed; the coating is stripped away like a banana skin. Chemical inhibitors have been incorporated, so that temporary protection is afforded for a short time if the part or tool is not used immediately after stripping off the outer coating. Other materials are applied cold by dipping or spraying, and likewise are stripped off in the same manner. This type of coating has proved very successful in the prevention of rust where exposure of metal to sea atmospheric and salt water is encountered.

Coating manufacturers have quickly realized the value of such types of coatings, and have developed materials for the protection of metal where severe corrosive conditions

prevail. Because many of these plastic bases are moisture proof, oil proof, acid and alkali proof, the range of application has been materially widened. New uses have been found for these materials because plasticizers can be incorporated, and they become much more flexible, withstanding wide temperature variations without cracking or checking. See Figures 5 and 6.

Materials are now available for the protection of the inside of oil storage tanks, where the steel bottoms and side sheets are subject to corrosion caused by the water in the bottom of these tanks. Tankers carrying petroleum products, especially to foreign ports, carry salt water as ballast in these tanks on their return trips. Severe corrosion takes place in these compartments, and coating and maintenance is a tremendous problem. Pumping rigs in the field, as well as oil storage tanks and gas and oil traps, present a constant film of oil on this equipment. Many industrial paints have not proved satisfactory because of the effect of the crude oil on the paint film. Considerable experimental work now is being carried on with the use of plastics for underground pipeline protection. What the results are going to be, no one knows. Sufficient time has not elapsed to give concrete evidence, and the data so far collected are only indicative.

Within the next few years, there should be tremendous advances in the development of these plastic base materials in the manufacture of protective coatings, and their uses will cover a very wide field.



The photographs attached to this report show what has been accomplished by proper protective measures, and what failures have occurred because of the improper materials and lack of an adequate maintenance program.

In conclusion, manufacturers of protective coatings are availing themselves of the most recent developments in scientific research, and are producing coatings which are designed for specific problems in all branches of industry. Coating manufacturers have failed in some phases, but if initial success is to continue, service must be a part of the organization. Too many times, protective coatings have been sold and no attempt made on the part of manufacturers to see that these coatings are applied according to specifications. As a result, many failures

have occurred because of poor cleaning procedure and faulty application methods; and materials have been unjustly condemned when, if a little attention had been given to coating operations, success would have resulted.

Manufacturers should make every effort to study any individual corrosion problem, approaching a solution from a chemical or engineering angle, and from the data obtained make intelligent recommendations as to the proper corrective measures to be followed. By such procedure, coating manufacturers and their engineers are better able to understand the operators' problems, bringing them into a closer personal touch with each other, and making for mutual understanding of the problems of corrosion.

### References

- (1) Eric Larson, Pipe Corrosion and Coatings.

## Discussion

**By J. R. Svrcek**

Dearborn Chemical Company

The points brought up by Mr. Hiskey concerning bond, preparation of surfaces, and selection of proper coatings cannot be over-emphasized. These have been substantiated by years of experience, ranging from the large corrosion prevention program of World War I and the following period of expanding industry, to the largest corrosion prevention program ever conceived so far, that of the protection for shipment of billions of dollars worth of valuable war equipment all over

the earth during World War II.

These points have been well covered. However, in enlarging on one aspect of Mr. Hiskey's paper, that of the use of plastic coatings in protection of vital equipment, the following can be said:

The relatively new types of protective coatings formulated from plastics or high polymer resins are gaining wide acceptance, due chiefly to a fine performance record in the field. These high polymer coatings, particularly of the vinyl type, are no

longer laboratory curiosities, but have full-fledged acceptance as coatings which will perform under certain extremely corrosive conditions, where other types of coatings cannot function because of an effect on the coating from chemical solutions or other materials. These coatings are not intended for surfaces which can be adequately protected by accepted, conventional coatings such as paints, petroleum base compounds, or bituminous materials. They have a definite application where severe corrosive conditions are encountered, and where specific resistance to chemical reagents and other materials is required. They have a larger number of desirable properties required for protection under these conditions than conventional coatings. They are tough and flexible over a wide range of temperature conditions. The property of toughness gives a coating with good abrasion resistance. Flexibility eliminates the deteriorating effect of constant expansion and contraction of metal surfaces under variations in temperature. Inertness to chemical action minimizes the effect of ordinary

weathering agents, as well as an additional solubility effect of specific solutions in contact with the coating. This inertness to chemical action is the most important property contributing to new coatings' success. Their resistance to most inorganic acids and alkalies, coupled with resistance to petroleum products, makes them effective coatings in the petroleum industry.

Mr. Hiskey has stressed in his paper that preparation of surface is one of the important factors in determining the performance of the coating applied. Although more care must be taken in the preparation of the surface for the high polymer coatings, the results obtained with these materials justify the added effort and expense.

Up to this date, few coatings used under the special conditions mentioned above have given a performance even approaching that of the high polymer coatings. They have a very definite place as coatings in maintenance of structures and equipment where corrosion has been tolerated simply because there never have been coatings which were capable of protecting them.

---

# Selenium Rectifiers for Cathodic Protection

By *W. F. Bonner*

Federal Telephone and Radio Corporation, Newark, N. J.

**T**HE SELENIUM RECTIFIER was introduced in the United States by the International Telephone and Telegraph Company in 1938. It previously had been commercially introduced in Europe in 1928, and its development there paralleled the development of the copper oxide rectifier in this country.

The selenium rectifier has had a meteoric rise in popularity since its introduction. Its electrical characteristics, long life, and light weight made it suitable for many applications in military as well as civilian equipment.

The demand by the armed forces for better performance and protection against all weather conditions gave great impetus to development during the war years. Work on rectifiers for aircraft applications resulted in the production of long-life plates of higher efficiency through their ability to withstand increased reverse voltages. Mechanical improvements in design also resulted from wartime developments.

These developments are available now in rectifiers which will withstand 45 percent higher back voltage per plate, in a change in design permitting complete protection against atmospheric conditions and in the addition to the plate sizes of a plate double the area of those previously made.

Rectifiers for cathodic protection

apparatus must operate satisfactorily unattended over long periods of time; must be able to furnish direct current in outdoor locations with minimum effect due to changes and extremes of temperature; must have good electrical efficiency; and must be capable of being protected against the effects of humid and salt-laden atmospheres. The selenium rectifier with center contact construction combines these features very favorably, and may be adapted economically to meet the widely varying voltage and current requirements of cathodic protection equipment.

A brief introduction to the characteristics of the selenium rectifier, so that they may be designed into equipment to their best advantage, is the purpose of this paper.

## Construction

A selenium rectifier plate is shown in Figure 1. Here is shown the base plate of steel or aluminum to which is applied a layer of crystalline selenium and a sprayed-on front-electrode. The cross section is drawn out of proportion in order to show the construction; actually the selenium and front-electrode layers are very thin. Rectification occurs at the boundary between the selenium and front-electrode, as a result of the formation of a barrier in that area which resists the flow of current from the front-electrode to the selenium, while offering but little resistance to a flow of current from

the selenium to the front-electrode.

Rectifier plates are made in various sizes; the most important have been the round plates  $\frac{7}{8}$  to  $4\frac{3}{8}$  inches in diameter. Sizes having active rectifying areas from 0.01 square inch to 25 square inches are shown in Figure 2.

The large rectangular plate is a recent addition to the line. It is designed particularly for heavy current applications. The rectangular plates permit greater economy of space and the large terminals simplify the connection to heavy leads or bus bar. Tentative current capacities of the two rectifier sizes using the large plate are given in Table I.

If the pressure necessary to hold rectifier stacks firmly assembled were applied to the active surface, the rectifier plates would be short circuited. Formerly no front electrode was applied near the center hole, and assembly pressure was applied in this area by a bakelite washer. A spring contact washer carried current from the center to the front-electrode and made electrical contact with limited pressure.

A recent development of great importance has eliminated the necessity for the spring contact washer. This development is the application

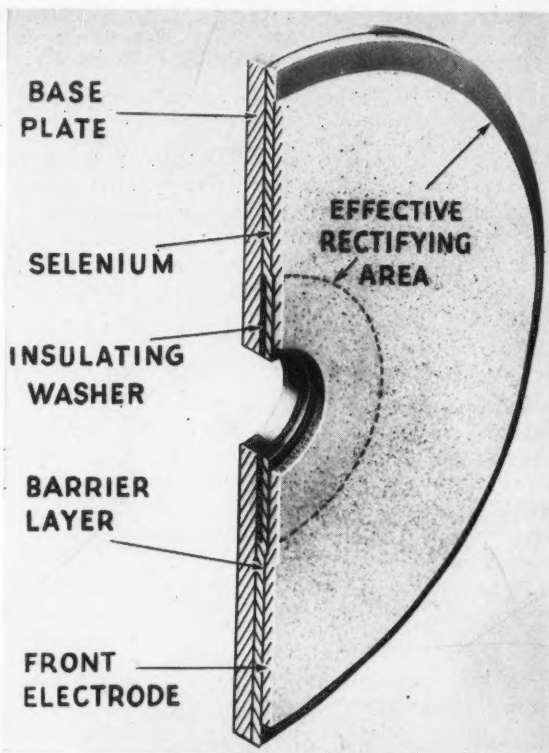


Figure 1—Cross sectional view of center contact selenium rectifier plate showing insulating washer.

of a thin non-conducting washer around the center hole of the base plate before the selenium is applied. This washer electrically insulates the base plate from the selenium. The front-electrode is applied over the selenium up to the edge of the center hole. Assembly pressure may be applied over an area somewhat smaller than the washer without affecting the rectifying action. If short circuits occur due to assembly pressure, the current resulting must flow through the selenium to the edge of the insulating washer; the resistance

**TABLE I**  
**Size and Current Capacity of Heavy Duty Selenium Rectifier Plates**

Type No.	Size, Inches	Max. RMS AC volts reverses per Plate	Maximum continuous DC amperes for one plate per arm at 35° C ambient, inductive or resistive load						Maximum continuous DC rating as value at 35° C ambient		Max. No. of Plates per Stack	Using Plate No.
			Single Phase			Three Phase			Amp.	Blocking Voltage		
			Half Wave	Bridge	Center Tap	Half Wave	Bridge	Center Tap				
128	6 $\frac{5}{8}$ "x4 $\frac{1}{2}$ "	26	4	8	8	10.6	12	15	6.2	22	42	128
130	6 $\frac{5}{8}$ "x4 $\frac{1}{2}$ "	26	5.2	10.4	10.4	13.8	15.6	19.4	8.0	22	30	128

of the selenium is high and the cross-sectional area very small so that current flow in a direction parallel to the base plate is negligible. At the same time the resistance of the front-electrode layer is low so that current will be conducted readily from all points on the active rectifying area to a point of electrical contact at the center.

A complete rectifier stack shown in Figure 3 is made up of a number of plates assembled on a stud covered with an insulating tube. Metal washers space the plates to allow

cooling air to pass through them and to make electrical connection to the front and back of each plate. Removal of the spring contact-washer which formerly covered a large portion of the front electrode of each plate has the advantage of allowing slightly better cooling, and the extremely important advantage of eliminating air pockets under the spring contact-washer. These unavoidable air pockets could not be sealed against moisture in an entirely satisfactory manner. The assembly shown in Figure 3 may be

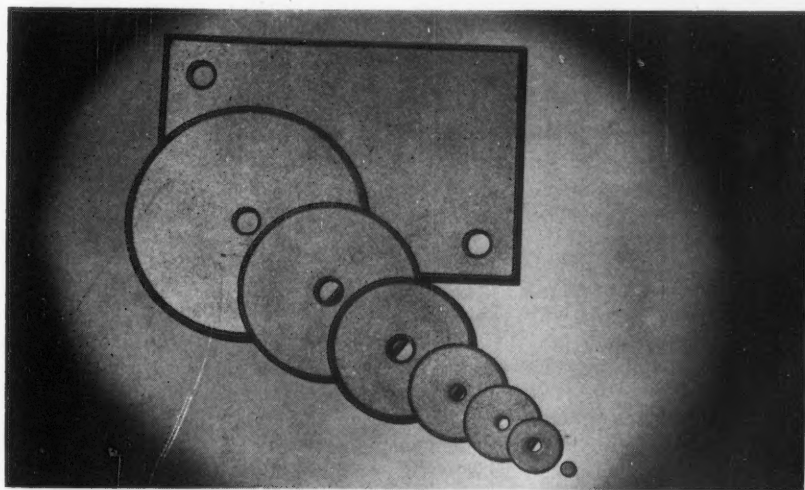


Figure 2—Popular sizes of selenium rectifier plates.

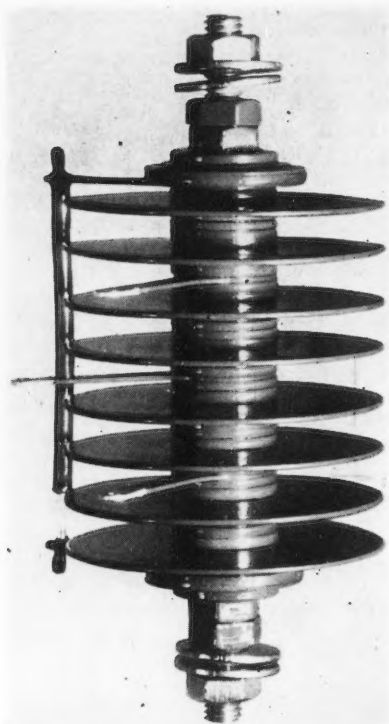


Figure 3—Typical center contact selenium rectifier stack assembly.

sprayed or dipped with as many coats of a protective finish as desired with an assurance of complete coverage.

Electrical connections are made by means of a terminal extending from the center to beyond the periphery of the plates. They are located centrally between the plates and at the end of the stack assembly as required.

The electrical connections of the single phase bridge rectifier are shown schematically in Figure 3-A. The triangles represent plates and the direction of current flow in the

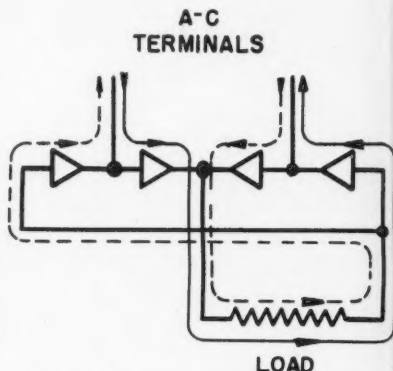


Figure 3-A—Single phase bridge rectifier showing typical arrangement of selenium plates in a stack and direction of current during each half cycle of the AC voltage resulting in full wave rectification.

conventional sense is indicated by the direction the triangle points along the stud. By various arrangements of the plates and connections of the terminals, various series and parallel combinations may be obtained.

The various components of a rectifier stack are shown in Figure 4. A spring cup washer included in the assembly at each end keeps tension on the stacks to reduce the possibility of fracture of the finish due to twisting in handling or expansion due to temperature changes.

#### Electrical Characteristics Forward and Reverse Currents and Voltages.

As stated previously, application of a steady potential in either direction to a selenium rectifier plate will result in a flow of current; but the resistance to flow in the direction from the front-electrode to the base plate (referred to as the reverse direction) is much greater than in the direction from the base plate to the front-electrode, or forward direction.



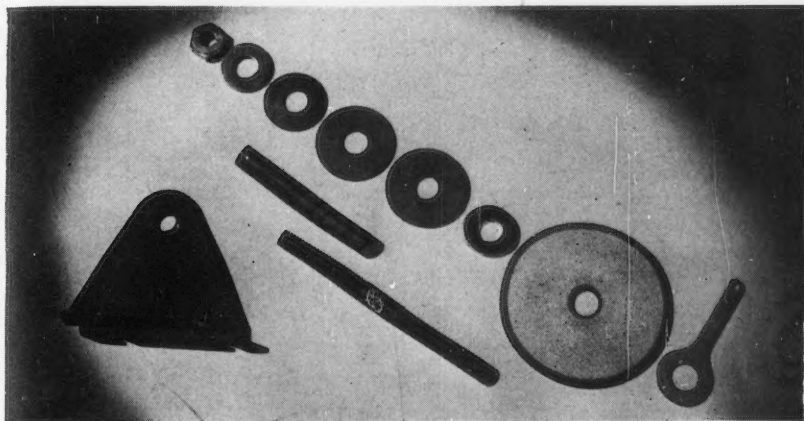


Figure 4—Components of a typical selenium rectifier stack.

In addition to changing resistance with change of direction of the applied potential, the resistance also changes with the magnitude of the

potential applied. Figure 5 shows the resistance of a unit area of a rectifier with various potentials applied in both the forward and reverse directions. The

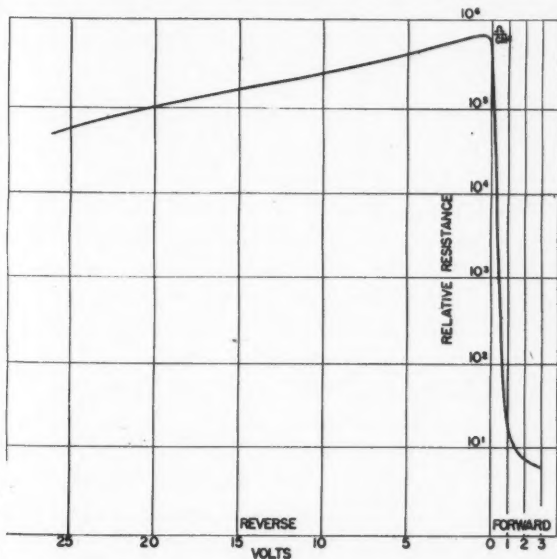


Figure 5—Typical static resistance curve of 26-volt selenium rectifier plate with varying forward and reverse voltages applied.

decrease in resistance with application of voltage to produce current flow in the forward direction is extremely sharp up to one volt, while voltage applied in the opposite direction causes a decrease in resistance but at a much less rapid rate.

Plotting current flow against applied voltage in both directions for a unit rectifier results in a curve as shown in Figure 6. Drawn to the same current scale, the reverse current is too small to be observed. The line representing

reverse current is drawn to a scale 100 times the scale of the forward current. Referring to the curve of forward voltage versus current, the effect of the negative resistance is shown in the relatively small increase in voltage drop with increase in forward current. This characteristic results in a rectifier with good voltage regulation.

In the forward or conducting direction, the selenium rectifier has a negative temperature coefficient. Figure 7 shows the increase in voltage drop across a plate with decrease in plate temperature. The drop curve shows voltage change with current loading corresponding to that used in normally spaced, convection-cooled stacks. The decrease in current due to this increase in voltage is not very great, as the voltage across the rectifier is usually a small portion of the voltage across the total circuit. A lighter loading of the rectifier will result in a more constant current with temperature change, as is indicated by the lower line, which shows approximately 60 percent increase at 0° C. for a current density of 5 ma per square centimeter against a 130 percent increase with a current density of 50 ma per square centimeter.

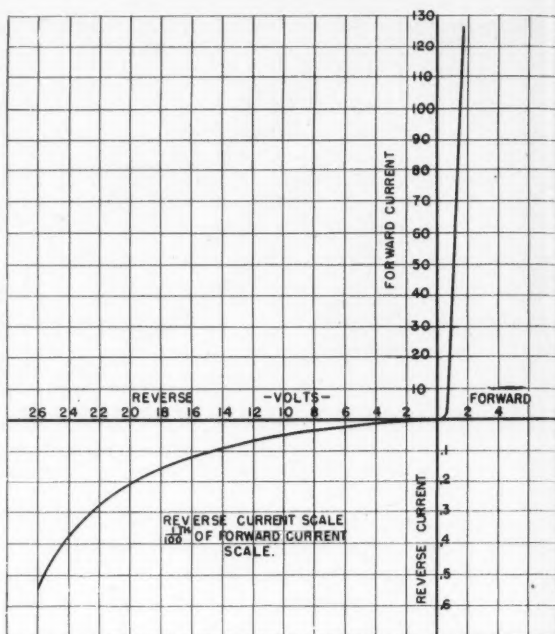


Figure 6—Typical curve of static forward and reverse current characteristics of 26-volt selenium rectifier plate.

The operating temperature of the plates is normally 25 to 35° C. above the ambient temperature at the usual room ambient. As the resistance of the rectifier is only a small part of the total circuit resistance, the effect on current flow at low temperatures is so slight as to be generally neglected. Figure 8 shows how the current changes with change in ambient temperature without readjustment of a-c voltage as shown by the solid line, and also shows the percentage increase in a-c voltage necessary to maintain a constant current in the load circuit.

The effect of temperature on the

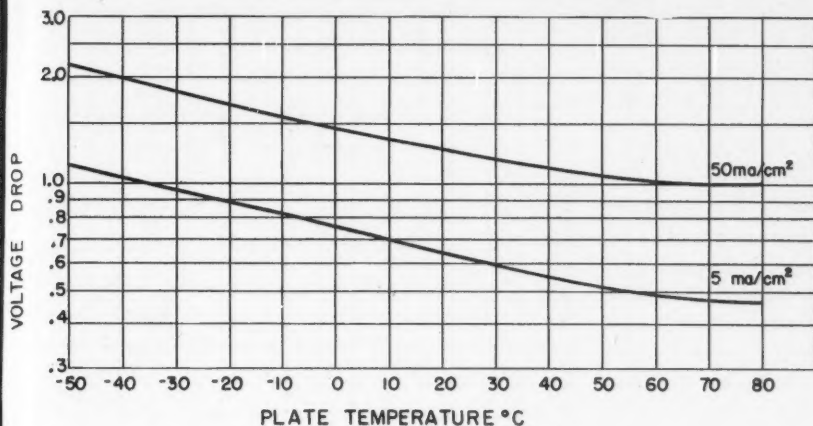


Figure 7—Relative voltage drop with plate temperature for 26-volt selenium rectifier plates at full load and 1/10 load.

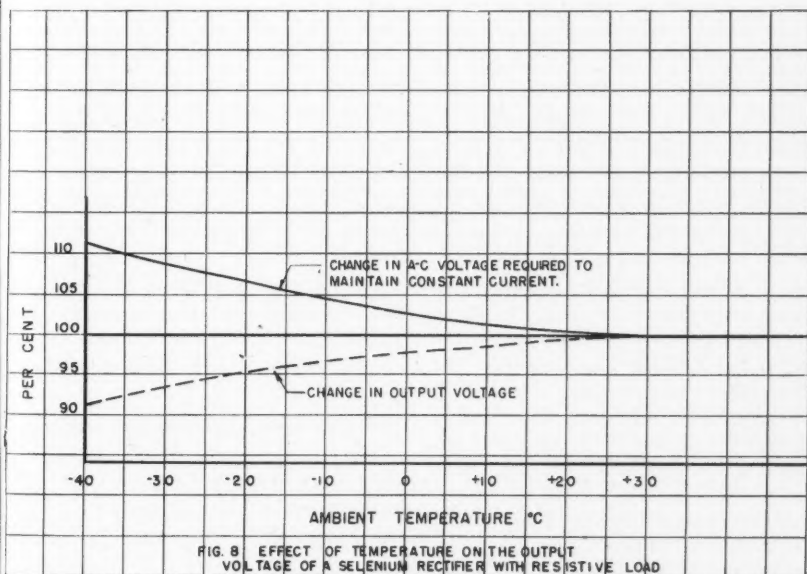


FIG. 8 EFFECT OF TEMPERATURE ON THE OUTPUT VOLTAGE OF A SELENIUM RECTIFIER WITH RESISTIVE LOAD

Figure 8—Effect of temperature on the output voltage of a selenium rectifier with resistive load.

leakage current is shown in Figure 9. It will be noted that with 18 volts applied the leakage current is quite constant. At voltages above 18 volts the leakage current decreases with increased temperature. This is a desirable characteristic as the heating due to reverse current is less at higher operating temperatures.

The rating of a rectifier is determined by the temperature rise of the plates. The temperature rise is the result of the wattage loss through the resistance of the rectifier in the forward direction due to the load current, and in the reverse direction due to the leakage current. For long life in continuous operation the operating temperature of a rectifier should not exceed 75° C.

The catalog ratings of the Federal selenium rectifier are based on continuous operation in an ambient temperature not over 35° C. Operating at the catalog rated values, the temperature rise will not exceed 30° C. new and 40° C. when the rectifier has aged. When it is required to operate in ambient temperatures above 35° C., the rectifier losses must be reduced so that the sum of the ambient temperature and the temperature rise of the rectifier does not exceed 75° C. Figure 10 shows the percentage reduction in current

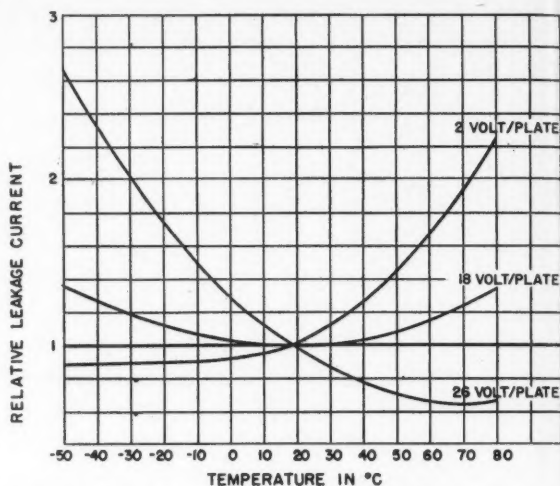


Figure 9—Variation in leakage current with plate temperature for 26-volt selenium rectifier plates at normal and reduced voltages.

and reverse voltage necessary to keep the temperature rise within satisfactory limits at higher ambient temperatures. As it frequently happens that the reverse voltage applied may be less than the permitted maximum, advantage may be taken of the decreased reverse losses resulting to allow a higher forward current. Examination of the figure will show optional currents at 50° and 60° C. ambients corresponding to the higher and lower values of reverse voltages shown directly above them.

#### Efficiency and Voltage Regulation

The electrical losses of the selenium rectifier are the total of the  $I^2R$  losses in the forward and reverse directions. These losses vary with the conditions of operation. The losses due to reverse current are constant if the a-c voltage is con-

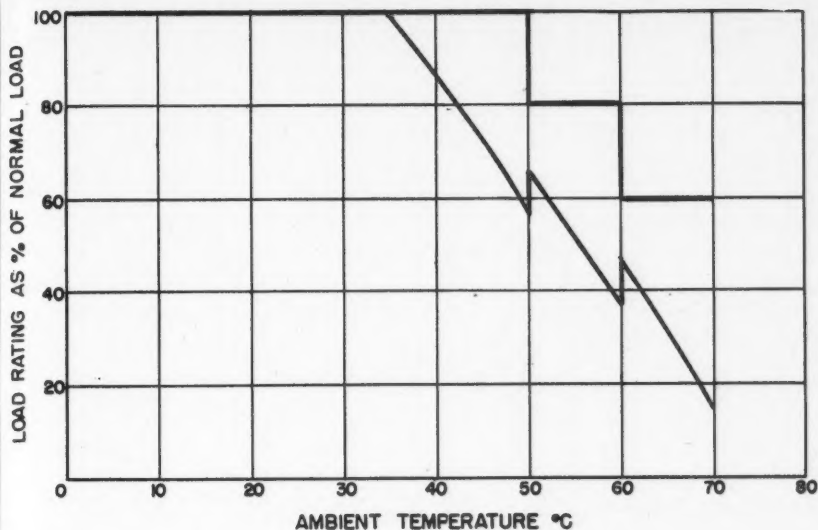


Figure 10—Load rating vs. ambient temperature for 26-volt selenium rectifier plate.

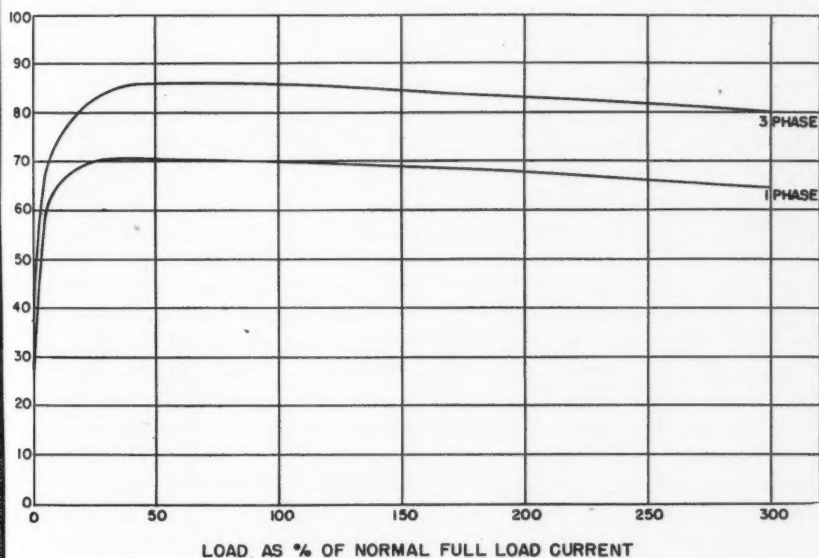


Figure 11—Typical efficiency curves of 26-volt selenium rectifier operating at full voltage.

stant while the losses, due to the forward current, vary with the current. The decrease in forward resistance with increase in current flow lessens the increase in  $I^2R$  loss, with the result that the efficiency is maintained near its maximum from 20 percent to 100 percent of full load. Figure 11 shows the efficiency at full reverse voltage per plate of the common rectifier circuits. These curves show efficiencies for loads up to 300 percent of full load of a normally spaced stack.

One hundred percent, or normal full load current, is the rated current for a rectifier assembled with the minimum standard plate spacing, or adding cooling fins to the stacks increases the amount of current it will carry with the same temperature rise. Stacks are made for continuous duty ratings up to 250 percent of the normal full load rating. The main effect of the increased current is to reduce the efficiency and give poorer voltage regulation. With the greater losses more air is required for cooling of the heavier loaded rectifier stack. If ventilation must be restricted to

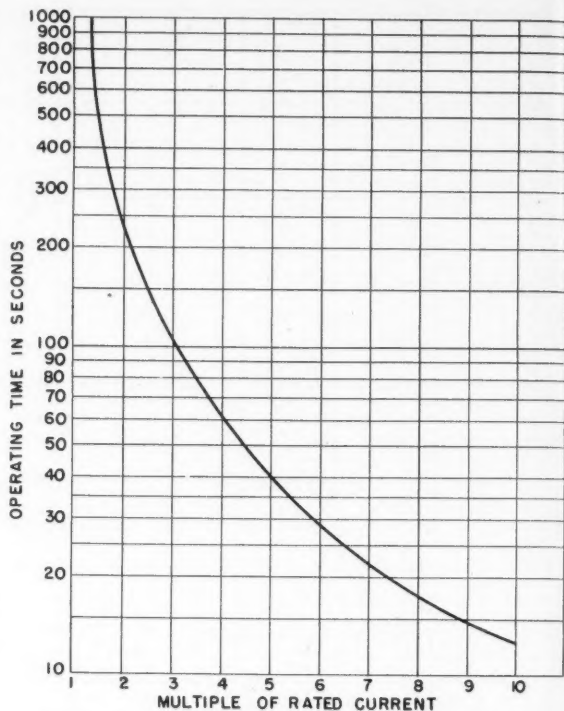


Figure 12—Curve showing typical operating time of the 26-volt selenium rectifier plate allowing time for cooling between each application of load.

keep out moisture and insects it is preferable to select a rectifier operating at near 100 percent of normal full load current.

While cathodic protection applications of selenium rectifiers call for continuous duty, there are other applications in which the rectifier is intermittently loaded. No increase in a-c voltage may be applied for even short intervals, but the current may be increased to produce up to the maximum safe temperature rise with resultant less expensive and smaller rectifier being required. The curve



TYPICAL RECTIFIER CIRCUIT CONNECTIONS AND CIRCUIT DATA

TYPE OF CIRCUIT	RECTIFIER TRANSFORMER	SINGLE PHASE FULL WAVE SINGLE PHASE CENTER TAP	SINGLE PHASE FULL WAVE (BRIDGE) SINE PHASE	3 PHASE HALF WAVE DELTA-WYE	3 PHASE HALF WAVE DELTA-WYE 240/120	6 PHASE HALF WAVE DELTA-STAR	6 PHASE HALF WAVE DELTA-6-PHASE TAP	6 PHASE HALF WAVE DELTA-DOUBLE WYE WITH BALANCE COIL	3 PHASE FULL WAVE DELTA-WYE	3 PHASE FULL WAVE DELTA-DELTA
CIRCUITS	SECONDARIES									
RECTIFIER PHASES	PRIMARYS	2	2	3	3	6	6	6	6	6
CURRENT PER RECTIFIER ARM		0.707	0.707	0.577	0.577	0.408	0.408	0.289	0.577	0.577
RECT. PEAK INV. VOLTS PER ARM		3.14	1.57	2.09	2.09	2.09	2.09	2.42	1.05	1.05
RECT. PEAK AMPS. PER ARM		1	1	1	1	1	1	0.5	1	1
TRANS. SEC. VOLTS PER ARM		1.11(A)	1.11	0.865	0.493(A)	0.740(A)	0.432(A)	0.855(A)	0.428	0.740
TRANS. SEC. AMPS. PER ARM		0.707	1	1.48	0.577	0.408	0.577(B)	0.289	0.816	0.471
TRANS. SEC. V.A.		1.57	1.11	1.48	1.71	1.81	1.79	1.48	1.05	1.05
TRANS. PRI. VOLTS		1.11	1.11	0.865	0.865	0.740	0.428	0.855	0.428	0.740
TRANS. PRI. AMPS.		1.11	1	0.865	0.471	0.471	0.816	0.408	0.816	0.471
TRANS. PRI. K.V.A.		1.11	1.11	1.21	1.21	1.28	1.05	1.05	1.05	1.05
TRANS. AVERAGE K.V.A.		1.34	1.11	1.35	1.46	1.55	1.42	1.26	1.05	1.05
LINE VOLTAGE		1.11	1.11	0.865	0.865	0.740	0.428	0.855	0.428	0.740
LINE CURRENT		1	1	0.865	0.865	0.740	0.428	0.855	0.428	0.740
LINE POWER FACTOR*		0.9	0.9	0.826	0.826	0.955	0.955	0.955	0.955	0.955
RIPPLE FREQUENCY		0.48	0.48	0.18	0.18	0.042	0.042	0.042	0.042	0.042
BALANCE COIL VOLTAGE		2 $\phi$	2 $\phi$	3 $\phi$	3 $\phi$	6 $\phi$	6 $\phi$	6 $\phi$	6 $\phi$	6 $\phi$
BALANCE COIL K.V.A.								0.427		
BALANCE COIL K.V.A. (AS EQUIVALENT TRANS.)								0.214(3 $\phi$ )		

THE ABOVE VALUES ARE FACTORS THAT EXPRESS THE RATIO OF THE R.M.S. VALUE OF THE CIRCUIT QUANTITIES DESIGNATED TO THE AVERAGE D-C OUTPUT VALUES OF THE RECTIFIER.

Figure 13.

CALCULATIONS ARE BASED ON A SINE WAVE VOLTAGE INPUT, PURE D-C CURRENT OUTPUT AND NO TRANSFORMER OR RECTIFIER LOSSES.  
\*P.F.=WATTS D.C./LINE VOLT-AMPERES A.C.

in Figure 12 shows the allowable increase in current permissible for various time intervals when time is allowed between operations for cooling to within 5° C. of ambient temperature.

The voltage regulation of a rectifier is a function of the forward resistance. Here again the decreasing resistance with increasing current in the forward direction partially offsets the increase in voltage drop through the rectifier. As a result, the forward voltage drop remains low through a wide change in load current. The voltage regulation of a single phase full wave rectifier is between 10 and 15 percent, depending on the current density and the size of plate. The greatest change in voltage occurs from zero to 20 percent of normal full load, resulting in a regulation between 20 percent and full load of between five and 10 percent.

### Circuits

Figure 13 shows typical circuit connections used with selenium rectifiers and may be helpful in determining transformer and wire sizes. The figures given assume no losses in the rectifier and transformer.

For cathodic protection work, the general practice has been to use single phase power. The cost of rectifiers is generally less for single phase units in capacities up to 1.5 KW. With outputs above 1.5 KW in a single rectifier, sufficient saving may be made through lower first cost and increased electrical efficiency to justify the use of a three phase circuit.

The use of the single phase center tap of the three phase half wave

circuits is sufficiently low to permit the use of one plate in series per arm, results in a saving of one-half the number of plates over a bridge circuit. The increase in transformer KVA required still leaves the cost of the installation in favor of the single phase center-tap or three phase half wave circuits. The output voltage which may be obtained from a single phase center-tap connected rectifier having one series plate per arm has been increased from six and one-half volts to 10 volts by the use of the new 100 series Federal selenium rectifiers. As many cathodic protection circuits may have upper voltage limits between eight and 10 volts, a definite economy may be affected in the cost of rectifier equipment in that voltage range. The increase in output voltage per plate in the center-tap and other rectifier connections is possible due to the ability of the 100 series plate to withstand a back voltage of 26 volts, whereas earlier plates will withstand 18 volts.

When a single phase rectifier is used to protect cables carrying telephone circuits, the AC components of the rectified current and its harmonics may induce voltages into the telephone circuits unless some form of filter circuit is used. Series reactance, parallel capacity (electrolytic type) or a combination of both will be found very effective in suppressing the 120 cycle fundamental and its harmonics.

The selenium rectifier may be used efficiently for power conversion in many fields of application. Equipments having fractional ampere ratings have been found satisfactory and powers up to 540 KW have been furnished in a single installation.

# "Thermogalvanic" Corrosion

By N. E. Berry

Servel, Inc., Evansville, Indiana

THE SUBJECT MATTER of this paper is based on unpublished work which is in fact somewhat incomplete. It then appears preferable to present at this time a rather general discussion of this subject, and to include only the data directly pertinent to that discussion.

It is regretted that such data cannot be accompanied by precise statements as to their limits of accuracy, but it may be confidently stated that they are sufficiently accurate for purposes of this general discussion.

It is hoped that in spite of the lack of complete data in this presentation, some information of immediate value will be found herein, and that in any case this discussion may suggest possibilities for additional lines of investigation by other laboratories interested in the general field of corrosion.

## General Considerations

The starting point in the consideration of any corrosion reaction is of course the driving force for the reaction as represented by the equilibrium or "reversible" potential. Although this is not a dependable indication of the reaction or corrosion rate, it does at least determine whether or not the reaction can occur at all. In most cases the reversible potential can be calculated either from available free energy data or determined directly by known methods of measuring galvanic potentials.

Consider for example the reactions listed below with their respec-

tive reversible potentials, the sign of the potential being chosen in accordance with the Lewis and Randall convention, so that a positive potential means that the cell reaction tends to go in the direction indicated by the chemical equation:

	$E_r$ (volts)
(1) $2\text{Fe} + 3\text{H}_2\text{O} + 3/2\text{O}_2$ (0.21 atm.) $= 2\text{Fe}(\text{OH})_2$	+ 1.12
(2) $\text{Fe} + 2\text{H}_2\text{O} = \text{Fe}(\text{OH})_2 + \text{H}_2$ (1 atm.)	+ 0.049
(3) $\text{Cu} + \text{H}_2\text{O} + 1/2\text{O}_2$ (0.21 atm.) $= \text{Cu}(\text{OH})_2$	+ 0.615
(4) $\text{Cu} + 2\text{H}_2\text{O} = \text{Cu}(\text{OH})_2 + \text{H}_2$ (1 atm.)	-0.604
(5) $\text{Cu} + 2\text{H}^+$ (1M) $= \text{Cu}^{++}$ (1M) $+ \text{H}_2$ (1 atm.)	-0.344
(6) $\text{Cu} + 2\text{H}^+$ (1M) $= \text{Cu}^{++}$ ( $10^{-10}\text{M}$ ) $+ \text{H}_2$	-0.049

Certain conclusions may be drawn from consideration of the magnitude of the potentials for the above reactions: One may conclude, for example, from (1) and (2) that iron can corrode in water or aqueous solutions, either in the presence of air (the partial pressure of oxygen being 0.21 atmosphere) or in the absence of oxygen (with hydrogen being evolved at a pressure of one atmosphere), although the driving force is greater in the presence of air. From (3) and (4) one may conclude that copper, under the same conditions, can corrode in the presence of oxygen but not in its absence.

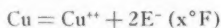
The negative potential for equation (5) indicates that copper cannot corrode in the absence of oxygen,

even when in contact with an acidified solution in which the concentrations of hydrogen ion and cupric ion are both at one molal. From (6) it may further be concluded that copper in contact with a 1M acid solution in the absence of oxygen will ordinarily corrode only to a negligible extent (less than  $10^{-10}$  mols per liter of  $\text{Cu}^{++}$ ).

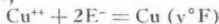
### Thermogalvanic Copper Cell

The specific system with which this discussion is largely concerned is of the type for which corrosion by reaction (5) above was shown to be impossible; i.e., copper metal in contact with an acidified solution of a cupric salt, such as cupric sulfate, and in the absence of oxygen. It has been demonstrated that whenever in such a system there exists a substantial temperature differential between two separated areas, very serious corrosion can occur. Such corrosion is of course decidedly electrolytic in nature and might then logically be termed "thermogalvanic" corrosion.

Any electrolytic reaction is usually represented by two separate and distinct electrode reactions, which reactions in fact occur at separated points or areas. In the case in question the anode reaction may be represented by the equation,



and the cathode reaction, by the equation,



The over-all result of this corrosion reaction is then the "migration" of copper from the anode to the cathode; or in other words, the anode is corroded and the cathode is

plated with the anode metal.

Although the operation of such a cell does involve the actual net transfer of certain substances (such as copper, cupric ion, transport ions, electrons, and solution) through a temperature gradient, it seems reasonable to assume that the only important source of electrical work is the reversible transfer of the latent heat ( $T\Delta S$ ) of the simple electrode reaction, from a higher to a lower temperature. If this assumption is made and other entropy transfers are then neglected, one may likewise neglect the entropy transfers involved in returning the system to its original condition and may treat the cell approximately as a heat engine with  $\Sigma\Delta S = 0$ .

For a thermogalvanic cell with electrode temperatures differing by  $dT$  degrees Kelvin, one may then write,

$$w = nF dE = T\Delta S dT/T = \Delta S dT$$

or,

$$dE/dT = \Delta S/nF$$

This may also be written as,

$$dE/dT (\text{volts } ^\circ\text{F}) = \Delta S/41,497$$

when  $\Delta S$  (in calories/ $^\circ\text{C}$ ) represents the entropy change associated with the simple anode reaction for the passage of one faraday of electricity. The reversible potential ( $E_r$ ) of any finite cell may then be estimated by integrating this equation between the two temperatures of the electrodes. When this calculation gives a positive value for  $E_r$ , one may predict that the higher temperature electrode will be the anode, and vice versa.

The data required for this estimate are the entropy values necessary for

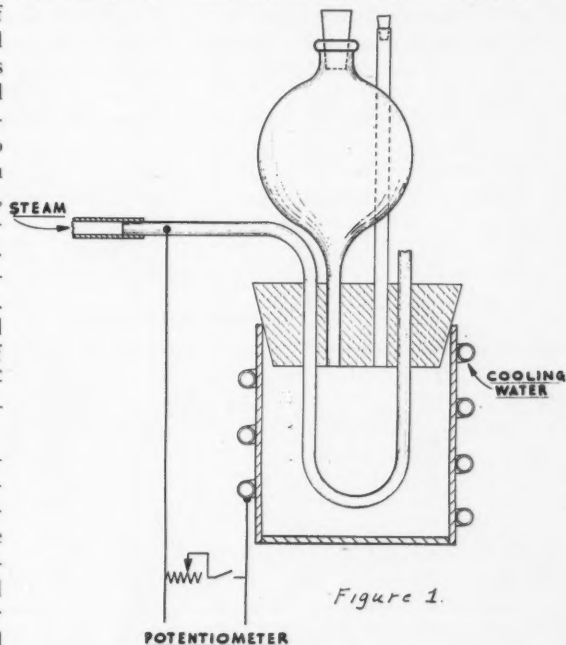
calculation of  $\Delta S$  for the simple electrode reaction. Although the required data are not directly available it has been possible, by making certain assumptions, to estimate  $dE/dT$  for the  $\text{Cu}:\text{CuSO}_4$  cell with copper sulfate at one molar concentration. The estimated average value is  $-0.53$  millivolts/ $^{\circ}\text{F}$ . This indicates that the low temperature electrode will be the anode and that, for example, with a  $100^{\circ}\text{F}$ . temperature differential a cell potential of about  $0.053$  volts should be realized which is a very substantial corrosion potential.

Potentials for this same cell have been determined experimentally both under equilibrium conditions and with current flowing. Measurements have been made for different current densities and also for different concentrations of copper sulfate. In all cases the solution was made tenth normal with respect to sulfuric acid in order to prevent the formation of basic precipitates, and a temperature differential of  $150^{\circ}\text{F}$ . was maintained between the electrodes. The type of cell used and the method of measurement are illustrated diagrammatically in Figure 1.

The vessel containing the electrolyte is made of copper and acts as one electrode. The vessel wall is cooled by circulating water through the attached

coil. A steam heated copper coil is inserted in the electrolyte through a rubber stopper, as indicated, which coil then acts as the other electrode. The rubber stopper serves as insulation between the two electrodes. When solution is introduced through the separatory funnel, the air in the vessel is displaced through the vent tube provided for the purpose. Electrode temperatures were measured by means of attached thermocouples.

The open-circuit or "reversible" potentials were measured with a type K potentiometer, and "operating" potentials were measured in like manner with the electrodes shorted through a known resistance as indicated. The data obtained with this cell are shown in Table I.



The average values for  $dE/dT$  were obtained by dividing  $E_r$  by the temperature differential, 150. The current was calculated in each case from the observed operating potential and the known resistance. The corrosion current,  $I_c$ , was determined in each case by plotting values for the operating current against corresponding values for the operating potential and extrapolating to zero potentials.

Current densities were calculated from the values for  $I_c$  and the electrode areas. In this case the heated electrode operated as the cathode while the cooled electrode operated as anode, as expected from the entropy calculation. The cathode area was 26.6 cm<sup>2</sup> and the anode area was 311 cm<sup>2</sup>. Values for the penetration rates were calculated directly from the anode current densities.

It is interesting to note the surprisingly good agreement between the calculated value of 0.53 millivolts/° F. and for  $dE/dT$  with one molar copper sulfate, and the observed average value of 0.536 for 0.94 molar copper sulfate. Although

this perfect agreement is undoubtedly somewhat accidental, it does appear to indicate the relative soundness of the approximations made in carrying out the calculations.

The data obtained show quite definitely that relative high corrosion rates are possible with this type of cell, particularly at the higher concentrations of copper sulfate. These results are all the more significant in view of the relatively low cathode area used, which makes it probable that the reaction is under cathodic control. If this is the case it is obvious that rather enormous corrosion rates would be obtained if the relative cathode and anode areas were reversed, or even if they were equivalent.

A visual demonstration of the corrosion produced by this cell was obtained by short-circuiting the cell (filled with approximately one molar cupric sulfate solution) through a resistance of 1 ohm for a period of about two hours. The cathode was then examined and was found to be covered with large crystals of metallic copper. The anode was quite

TABLE I  
Thermogalvanic Cell Data

Conc. of Cu** (m/l)	$E_r$ (Millivolts)*	Av. $dE/dT$ (Mv/°F.)*	$I_c$ (Milliamps)	Anode Current Density (ma/cm <sup>2</sup> )	Cathode Current Density (ma/cm <sup>2</sup> )	Av. Anode Penetration (Inches./yr.)
0.940	80.5	0.536	58.0	0.186	2.18	0.086
0.397	79.5	0.530	48.5	0.156	1.82	0.072
0.192	78.3	0.522	37.4	0.120	1.40	0.055
0.062	72.3	0.482	28.2	0.091	1.06	0.042
0.042	67.6	0.451	23.8	0.076	0.90	0.035
0.019	61.5	0.410	15.3	0.049	0.58	0.023
0.0138	55.5	0.370	13.2	0.042	0.50	0.020
0.0041	49.0	0.327	8.4	0.027	0.32	0.012
0.0030	42.9	0.286	4.6	0.015	0.17	0.007
0.0011	38.4	0.256	3.7	0.012	0.14	0.005
0.0002	34.9	0.233	1.4	0.004	0.05	0.002

\* Strictly speaking, these values should all bear the negative sign. It appears simpler however, to state merely that in this cell the low temperature electrode is the anode, and that the values listed then represent the magnitude of the driving force for such a cell.



bright and apparently uniformly corroded. It is not difficult to imagine what the results might have been had the cell been connected through a dead short for a longer period of time. (A similar demonstration was made with a Pb:PbAc cell and again numerous metallic crystals were observed, after a period of time, on the hot electrode.)

The effect of the cupric ion concentration on the current density or anode penetration is a matter of particular interest, and is in fact of utmost practical importance. It will be noted that the corrosion rate decreases with decreasing cupric ion concentration, by a factor of about 40 for the range of concentrations investigated. At the same time the reversible potential for the cell decreases by a factor of only 2.3. The decrease in corrosion rate is no doubt due largely to the increasing importance of "concentration polarization" as the cupric ion concentration is decreased. As this concentration approaches zero, a condition is in fact approached which is somewhat analogous to the age-old question of "the hen and the egg." It will readily be seen that in this type of cell a copper ion cannot be produced at the anode unless a copper ion is simultaneously discharged at the cathode. At zero concentration no copper ion is available at the cathode therefore one cannot be produced at the anode. Yet a copper ion cannot be made available at the cathode until one is produced at the anode. A rather fortunate stalemate is of course the result.

It then seems safe to predict that copper systems when in contact with electrolytes other than copper solutions should generally be comparatively free of thermogalvanic

corrosion. However, there is always the possibility of contamination of the electrolyte with copper salts produced by means of some other reaction, as for example by oxidation either before the electrolyte is introduced, or by subsequent oxidation.

When, for example, the electrolyte is an acid solution in contact with air, continued oxidation could result in appreciable concentration of copper ion, and thermogalvanic corrosion could then take place. With neutral or alkaline solutions, however, the copper ion concentration cannot rise appreciably beyond that in equilibrium with the corresponding insoluble oxide or hydroxide, which concentration is generally quite low. In the case of ammonia or halide solutions where a complex ion is formed, the copper ion concentration could again become relatively high and thermogalvanic corrosion could be a real danger.

#### Other Thermogalvanic Cells

It will now be of interest to examine the possibilities for this type of corrosion with other metals. The values of  $dE/dT$  for a number of other metal couples have been estimated, again somewhat indirectly (1); and in view of the close agreement obtained between the calculated and observed value for copper it is believed that these estimates are fairly dependable. The values calculated for zinc, iron, cadmium, lead, and tin, in each case in contact with one molar solution of their ion, all fall within a factor of two of each other and of that for copper. Also they are all in the same direction, i.e., the hot electrode is the cathode. It should, however, be pointed out that there is no reason to expect that the higher temperature electrode will always

be the cathode. In fact there is some indication that the silver couple, for example, would be reversed. The formation of a complex ion may also reverse the couple for any of the metals investigated. It has been experimentally demonstrated that the copper couple with cuprous complex halide ion has the reverse potential. Corrosion cells for which the potential is reversed are likely to be especially hard to control by reducing the concentration of the metal ion, as theory indicates that the reversible potential would be increased thereby, thus partially off-setting the effect of increased polarization.

Although no thermogalvanic potentials have as yet been measured for iron couples, the high predicted values indicate definite possibilities for this type of corrosion in ferrous metal systems. Generally speaking, in neutral or alkaline solutions, the concentration of ferrous or ferric ion that could be attained is limited by the solubility of their respective hydroxides; and the possibility of serious thermogalvanic corrosion is limited correspondingly. However, in slightly acid solutions the equilibrium concentration of ferrous ion increases sharply, and it should then be quite possible for the thermogalvanic cell to become a prominent factor in corrosion. Under these conditions, the metal ion concentration required to "catalyze" the thermogalvanic reaction can be supplied by the normal hydrogen forming reaction or by reaction between iron and any oxygen present.

Even in neutral or alkaline solutions it would seem possible for thermogalvanic corrosion to occur to an appreciable extent as a result of the presence of ferrous hydroxide. In

this case iron could go into solution at the anode to form ferrous hydroxide, while ferrous ions are being discharged from the saturated solution at the cathode. The depletion of ferrous ion at the cathode could then be off-set by the further solution of ferrous hydroxide. With the information available it is difficult to guess what the rate-determining step might be in any such corrosion process. However, if the rate should depend largely on the transfer of ferrous hydroxide from the anode to the cathode, it is not difficult to imagine circumstances where it might be relatively high. A liquid heat-exchanger, for example, where one colder wall is directly above a hotter wall might result in fairly rapid transfer of insoluble ferrous hydroxide from anode to cathode by means of sedimentation.

A number of years ago, the author had occasion to install an all-steel evaporator for the purpose of concentrating sodium citrate solutions. The possibility of corrosion was recognized in view of the known existence of a very stable ferric-citrate complex ion, and corrosion tests were made with steel specimens in sodium citrate solution and also by boiling sodium citrate solutions in steel vessels. All tests indicated negligible corrosion. However, during operation of the steel evaporator, which was subsequently installed, very severe corrosion was encountered with no detectable evidence of hydrogen formation.

It now seems likely that this was actually a case of thermogalvanic corrosion, but that in the initial tests, corrosion did not occur because of the absence of any appreciable temperature differential. In citrate

solutions, the formation of the complex citrate ion of course greatly increases the solubility of the metal ion; and the "catalyst" for thermogalvanic corrosion can then be made available in sufficient concentration to make such a corrosion reaction very likely indeed.

Another instance where the thermogalvanic cell may possibly be an unrecognized factor is in the corrosion of caustic evaporators and caustic fusion pots. In this case the "catalyst" might result from the slightly amphoteric property of iron hydroxides which in strongly alkaline solutions results in appreciable solubility of the metal ion.

It seems quite possible, or perhaps even probable, that a number of other cases of thermogalvanic corrosion have been encountered, particularly in the chemical industry; and in any case it is not difficult to imagine conditions under which it might readily occur. The primary requirements are the presence of an appreciable concentration of a salt of the metal concerned, and a temperature differential between two areas in the system which are electrically connected through metal and solution.

It is amusing to contemplate what

might happen if one should use a gold vessel for purposes of heating gold chloride solutions under conditions such that an appreciable temperature differential is maintained. It is certainly possible that serious corrosion of the gold vessel might be encountered over a period of time.

It may also be of interest to note that there is some similarity between "thermogalvanic" cells and true "concentration" cells since both result in "migration" of the anode metal to the cathode. It might further be noted, however, that in the case of a cupric ion concentration cell, a hundred fold difference in concentration would be required to produce a potential comparable to that resulting from a 100° F. differential temperature in the corresponding thermogalvanic cell.

#### Acknowledgment

The author wishes to make acknowledgment to Dr. P. P. Anderson and E. M. Stubblefield for the experimental work covered in this paper, and to Dr. R. M. Buffington for the major part of the theoretical calculations as well as for suggestion of the term "thermogalvanic" to represent the type of cell discussed herein.

#### References

1. Lewis and Randall, "Thermodynamics," McGraw-Hill (1923).
2. W. M. Latimer and R. M. Buffington, *Journal American Chemical Society*, **48**, 2297 (1926).
3. E. D. Eastman, *J. Amer. Chem. Soc.*, **50**, 292-7 (1928).
4. W. M. Latimer, K. S. Pitzer, and W. V. Smith, *J. Amer. Chem. Soc.*, **60**, 1829-31 (1938).

# Corrosion Criteria — Their Visual Evaluation

By Marc Darrin

Chief Research Chemist, Research and Development Dept., Mutual Chemical Company of America, Baltimore, Md.

PANELS exposed in aqueous media frequently do not corrode uniformly. Many show signs of local attack, especially on edges or corners. For these panels weight-loss comparisons are meaningless (2) unless made between panels having essentially the same type of corrosion. An opinion as to the reliability of these comparisons may be based on the nature of the localized corrosion. Obviously if localized corrosion is limited to pits of about the same number and depth on two panels, their relative order of corrosion resistance may be based on weight loss—but the primary criterion which places these two panels in the same class is the nature of the corrosion.

## Visual Scoring

For these reasons our laboratory, for the past six years, has used a visual scoring method supplemented by the customary weight-loss data. Scores are obtained by marking various criteria of corrosion on a prepared form (Form 1) which is converted to a numerical basis by weighting the importance of each corrosion criteria for the particular application under consideration. A method of doing this has been described by the author (2). A somewhat similar but more complicated

method of visual comparison has since been suggested by F. A. Champion (1). Although the latter method is very good from the theoretical viewpoint, there are several reasons which limit its practical application: first, its complication and use of special radiographic equipment; second, the use of seven terms to differentiate degrees of corrosion: namely, (1) minute, (2) very small, (3) small, (4) moderate, (5) considerable, (6) large, and (7) very large. These words represent too small differences to be duplicated by independent observers.

In the present procedure only four are used to describe the amount of local corrosion, namely, (1) none, (2) slight, (3) moderate, and (4) bad. It has been found that almost anyone with a little experience can check on a prepared form whether local corrosion is slight, moderate, or bad. Having done this the observer checks on the next line (Form 1, section A) whether the depth of the local corrosion is slight, moderate, deep, or very deep. Ordinarily this can be judged by the eye; however, if depth measurements are made, the relation shown in Table I may be employed (3).

In a similar manner evidence of general corrosion is checked. Other corrosion criteria such as discoloration and roughening are checked also.

Reprinted from A.S.T.M. Bulletin, 1946, No. 138, 37-39, January.

*Roughening:*

The degree of roughening corresponds to Champion's (1) "even" and "uneven" types of corrosion, but the method described here is simpler. It amounts to deducting more for local corrosion than for general corrosion, deducting a little more if either is roughened, and still more if pitted, the precise amount of each deduction being based on three or four readily discernible degrees. The figures given in Form 1 automatically provide for these deductions.

*Corrosion Score of Panel:*

Having checked the degree of all corrosion criteria on the prepared form, the numerical values assigned to each are added. For example, if the specimen was badly attacked in respect to all corrosion criteria, values on the extreme right (Form 1, section A) would be checked and their sum would be zero. The sum of the values at the extreme left is 40, which represents a perfect specimen. The obtained sum may be converted to the basis of 100 equals a perfect panel by dividing by 0.4, but this is the corrosion score of the panel only, not of the system.

*Bimetallic Systems (2):*

If the system is bimetallic, section B, Form 1, should be checked for the contact metal; but, since this metal is usually cathodic and has almost a perfect score, namely, 40, its detailed inspection is not always

essential. For instance, if copper is in contact with an iron panel, in an ordinary aqueous medium, it is permissible to assume that the corrosion score of the copper is 40, unless it happens that discoloration of the copper is of some importance in which case the score of the copper may be reduced from one to three points as provided in the form.

*Liquid Media:*

If the condition of the liquid is important, as in a recirculating cooling water system (6) or refrigeration brine (7), section C, Form 1 should be checked. If the condition of the liquid is of no importance, its score may be considered as 20. Likewise any other corrosion criterion which is of no importance for a particular application may be scored as perfect when making comparisons for that particular application.

*Corrosion Score of Systems:*

The sum  $A + B + C$  (Form 1), is the corrosion score of the system on the basis of 100 equals a perfect system. If there is no contact metal, or if the contact metal is unattacked or its condition unimportant, B equals 40. If there is no contact metal in a series of tests which are being compared only between themselves, it is permissible to disregard factor B and compare on the basis of 60 equals perfect. As mentioned, if the condition of the liquid is of no importance, factor C may be considered as 20.

Various modifications of the above procedure and weightings have been tried, and it has been found that one described is most generally applicable. Irrespective of what weightings are used, the data may be recalculated at any time for special comparisons or for other weightings

TABLE I  
General Meaning of Pit-Depth Terms (3).

Designation	Depth of Corrosion, Inches
None.....	<0.001
Slight.....	0.001 to 0.004
Moderate.....	0.005 to 0.014
Deep.....	0.015 to 0.030
Very deep.....	> 0.030

## FORM 1

## Visual Inspection Before Cleaning (2, 3).

Sample No. .... Ref. No. .... Time Exposed. .... Temp. ....  
 Description .....

**A. Condition of Specimen (40)**

1. Discoloration (none 3, slight 2, moderate 1, bad 0)
2. Roughening (none 4, slight 3, moderate 2, bad 0)
3. Local corrosion (none 9, slight 6, moderate 3, bad 0)
4. Depth of pits (none 12, slight 9, moderate 6, deep 3, very deep 0)
5. General corrosion (none 12, slight 9, moderate 6, bad 3, very bad 0)

**B. Condition of Contact metal if present (40)**

1. Discoloration (none 3, slight 2, moderate 1, bad 0)
2. Roughening (none 4, slight 3, moderate 2, bad 0)
3. Local corrosion (none 9, slight 6, moderate 3, bad 0)
4. Depth of pits (none 12, slight 9, moderate 6, deep 3, very deep 0)
5. General corrosion (none 12, slight 9, moderate 6, bad 3, very bad 0)

**C. Condition of Liquid (20)**

1. Cloudiness (none 4, slight 3, moderate 2, bad 0)
2. Precipitate (none 8, slight 5, moderate 2, bad 0)
3. General appearance (good 8, fair 6, poor 4, bad 2, very bad 0)

**Corrosion Score (A + B + C) .....**

**Remarks. ....**

Date ..... Observer .....

## FORM 2

## Examination After Cleaning (4).

Sample No. .... Ref. No. .... Time. mdd\*. .... Area. .... Metal. ....  
 Weight loss: ..... g. .... mdd\*. .... ipy\*\*

Appearance of cleaned panel (excellent, good, fair, poor, bad, very bad) .....

Corrosion Types	Order	Number	Depth
1. Discoloration .....	_____	_____	_____
2. General corrosion, even .....	_____	_____	_____
3. General corrosion, uneven .....	_____	_____	_____
4. Large local corrosion areas, even .....	_____	_____	_____
5. Large local corrosion areas, uneven .....	_____	_____	_____
6. Wide pits .....	_____	_____	_____
7. Elongated pits .....	_____	_____	_____
8. Medium or rounded pits .....	_____	_____	_____
9. Narrow pits .....	_____	_____	_____
10. Blister pits .....	_____	_____	_____
11. Erupted pits .....	_____	_____	_____
12. Perforation of coating .....	_____	_____	_____
13. Perforation of panel .....	_____	_____	_____
14. Cracks .....	_____	_____	_____
15. Edge or corner corrosion .....	_____	_____	_____
16. Attack near bimetallic contact .....	_____	_____	_____
17. Water line corrosion .....	_____	_____	_____
18. Selective attack .....	_____	_____	_____
19. Erosion .....	_____	_____	_____
20. Defects or injury .....	_____	_____	_____

**Media Analysis, at start .....**  
 at end .....

pH at start ..... at end .....

Compare with .....

**Remarks: .....**

**Directions:** In the column marked "number" record the number of pits on the panel (including edges) per 12 sq. in. of surface up to > 5 pits. Under "depth" show the depth of the deepest pit to the closest thousandth-inch from < 0.001 to > 0.030 in (exclusive of pits whose centers are less than 1/8 inch from edge). Under "order" check the predominating types of corrosion, and indicate their relative order of severity.

\* Milligrams per square decimeter per year.

\*\* Inches penetration per year.



which may be decided upon later.

#### *Meaning of Corrosion Score (4):*

Sometimes it is more convenient to designate the general degree of corrosion resistance as "good," "bad," etc., rather than by a numerical corrosion score. A system for doing this is shown in Table II. This method of indicating corrosion resistance by a descriptive word rather than a score number is advantageous in comparing systems which are not closely related, or systems where there has been very severe corrosion. This is because a few points of difference may have no significance for such comparisons.

#### **Personal Factor**

All corrosion tests during the past six years were checked with close agreement by four men, one of whom was the author, and one of whom was usually a new man with little or no corrosion experience. After examination of a few panels, there was almost no difference between the results reported by a new man and an experienced man. These tests included several thousand panels of ferrous and non-ferrous metals, and bimetallic combinations, in various media for long periods of time under a variety of conditions (2-5).

#### **Types of Corrosion**

It has been found very helpful, in addition to the foregoing, to indicate in more detail the types of corrosion. In order to do this each type of corrosion, as it appears to the eye on the cleaned panel, may be assigned a number, which is recorded in the sequence of its predominance. The numbers which were assigned to the various types of corrosion about three years ago have been previously reported (4). These num-

**TABLE II**  
**General Meaning of Corrosion Score (4).**

Designation	Score	Degree of Corrosion
Perfect.....	100	No indication.
Excellent.....	Above 95	Minor, but very satisfactory.
Good.....	85 to 95	Definite, but probably satisfactory.
Fair.....	75 to 84	Questionable.
Poor.....	65 to 74	Probably unsatisfactory.
Bad.....	Less than 65	Severe corrosion.

bers provide information as to both the character and the location of the corrosion. With this information accompanying customary corrosion data, reliable recommendations for specific applications may be made by an experienced engineer.

The arrangement of these corrosion type numbers was an arbitrary one which had grown and was changed from time to time as difficulties were encountered. This arrangement, though quite satisfactory for most practical applications, has limitations; and the selection of names and their sequence is not very logical from the theoretical viewpoint. For these reasons a revised arrangement with better nomenclature is suggested, as shown in Form 2. This has two classes of general corrosion, namely, even and uneven. Two intermediate classes of local corrosion are provided between general corrosion and wide pits, and dezincification is included under the general classification of selective attack.

Undoubtedly other improvements can be suggested, and this is one of the purposes of this discussion. Equally important is bringing to the attention of various A.S.T.M. corrosion committees the desirability of uniform nomenclature for different types of corrosion, and

eventually assigning a number or other symbol to each. Of course it would be desirable to do this before the present procedure becomes too firmly established.

### Summarized Procedure

1. *Before cleaning* the panel, its appearance is checked on section A of Form 1. If the system is bimetallic, the contact metal is checked on section B. If the condition of the liquid is of importance, this is checked on section C. Any criteria that are unimportant for a particular application may be checked as perfect when comparisons are required only for that particular application. The sum of the corrosion criteria weightings is the score. The general meaning of this score is shown in Table II; but, in order to re-evaluate for specific applications, the following more detailed information may be required.

2. *After cleaning* the panel, the types of corrosion may be classified in greater detail on Form 2. Spaces are provided also on this form for analysis of liquid, pH changes, general appearance, weight loss and derived data.

3. *To compare panels or systems*, the principal data on Forms 1 and 2 are recapitulated. This may be done on a third form (not shown) having columns for tabulation of the following information, as may be pertinent for the application under consideration: panel number; conditions of test; analysis of liquid; inches penetration per year; types of corrosion, recorded in sequence of severity; depth of deepest pit, followed by its type symbol; corrosion score of system or panel; appearance of cleaned panel.

If there is no significant difference (other than weight loss) between the above data for panels that are being compared, their order of corrosion resistance may be based on weight loss figured as inches penetration per year. Otherwise, they should be divided into groups such as those shown in Table II. Those in the top groups which do not show signs of severe local attack may be arranged in order of inches penetration per year; while those in lower groups should be arranged according to depth of pitting or other criteria of local attack.

### References

1. F. A. Champion, New Methods for Examination of Corroded Metal, *Jnl. Inst. Metals* (London). Vol. 69, pp. 47-66 (1943).
2. Marc Darrin, Chromate Corrosion Inhibitors in Bimetallic Systems, *Ind. and Eng. Chem. Anal. Ed.*, Vol. 13, pp. 755-759 (1941); *Proceedings, Ann. Water Conference, Engineering Soc. Western Pennsylvania*, Vol. 2, pp. 59-69 (1941).
3. Marc Darrin, Chromate Corrosion Inhibitors in Brine Systems ASRE Corrosion Report, *Am. Soc. Refrigerating Engineers*, pp. 21-27 (1944).
4. Marc Darrin, Chromate Corrosion Inhibitors in Bimetallic Systems—Technology under Conditions Encountered in Practice, *Ind. and Eng. Chem.*, Vol. 37, pp. 741-749 (1945).
5. Marc Darrin, Chromate Corrosion Inhibitors in Chloride Systems—Rate of Consumption of Chromate, *Ind. and Eng. Chem.* (to be published).
6. Mutual Chemical Company of America, Chromate Corrosion Inhibitors for Internal Combustion Engines, *Serial No. 33* (1945).
7. Mutual Chemical Company of America, Corrosion Control in the Refrigeration Industry—The Chromate Treatment of Brine, *Serial No. 34* (1946).

## Discussion

By F. L. LaQue

International Nickel Company, New York, N. Y.

Mr. Darrin's paper represents a welcome step toward a more orderly description of the corrosion of test specimens beyond what can be indicated by data on weight loss, changes in mechanical properties, or other alterations that can be measured quantitatively and described numerically.

In this connection, it should be noted that something along the same line is receiving attention by the American Coordinating Committee on Corrosion through a Subcommittee on Standard Terms and Symbols. The organization of this subcommittee stemmed, in part, from methods for the examination of corroded metal proposed by F. A. Champion (1)—referred to by Mr. Darrin in his paper—and in part from somewhat similar systems of classification being used in some corrosion laboratories in this country. Mr. Darrin's proposals will, no doubt, be of interest to this committee in working out a generally applicable scheme that will provide adequately for such special types of corrosion investigation as the one for which Mr. Darrin developed his rating system.

Mr. Champion proposed numerical definitions of descriptive adjectives, such as few, small, severe, etc., as applied to the number, size, and intensity of forms of local attack in much the same way that Mr. Darrin defined terms related to depth of attack. Champion also

provided supplementary charts to illustrate graphically the terms for type, number, size, and intensity of attack which would seem to be a useful part of any scheme of classification.

It seems desirable to draw attention to the fact that the proposed terms for describing depths of pits, and particularly their relation to each other, are significant only with respect to specimens exposed for the same length of time. It would not be proper to assume that a "deep" pit (0.015 to 0.030 in.) that developed in a 10-day test had the same significance as a similar "deep" pit that developed to the same depth during exposure of a specimen for ten years. For this reason, the writer is inclined to question the desirability of using descriptive adjectives instead of simply stating the depth of pits which have to be measured, or estimated anyway, before the adjectives may be used properly according to Mr. Darrin's Table I.

In view of the distorted relationships among exposed area of specimen, volume of solution, and time of contact that may exist in laboratory tests as compared with actual practice, one is inclined to question the assignment of numerical values to the different conditions of the testing liquid after test (section C of Form 1), or at least the combination of these relatively uncertain values with the more precise descriptions of the test specimens in

arriving at a numerical measure of the over-all desirability of a particular system.

In conclusion, the writer wishes to emphasize his hope that this con-

tribution by Mr. Darrin will excite further interest in the development of more or less standardized terms and symbols for the description of corrosion of test specimens.

### **Author's Rebuttal**

*By Marc Darrin*

An important purpose of this discussion is to invite helpful comments such as Mr. LaQue's. Although we are in general agreement there are some differences of opinion with respect to detail, which we shall endeavor to clarify.

There is no objection to recording the precise depth of pits (which is ordinarily done for purpose of checking), but it has been our experience that there is no significant difference in corrosion resistance within the ranges given in Table I. Since these ranges often may be judged by the eye, and since their use simplifies recapitulation of data and exchange of pertinent information, it is frequently advantageous to employ them.

Regarding time of exposure, this method provides for comparisons only between panels exposed for the same period of time, which should be noted on the first line of Form 1. How long an exposure should be is beyond the scope of this discussion; however, we have tried many periods from a few hours to over six years, and have not found any metallic system which failed to indicate its true trend within six months in an aqueous medium. It may be that this does not apply to atmospheric corrosion or to panels with organic coatings.

Mr. LaQue questions the inclusion of values for the different conditions of the testing liquid after the test. As we have pointed out, these criteria, and many others, may be omitted if they are of no importance for the application under consideration. For example, the condition of the liquid is of no importance in the selection of metals of construction for a once-through heat exchanger. In this case the deciding factor is the increased life which could be reasonably expected if the tubes, tube-plates, or shell are made of a very corrosion-resistant metal such as nickel, chromium-nickel steel or monel. On the other hand, it is important to know the condition of the liquid when selecting the proper treatment of the water in an existing recirculating system, especially if corrosion products might clog spray nozzles or other narrow passages. This is commonly the case with all manner of cooling towers which are employed for air conditioning, engine jacket cooling, condensers, and the like. In these cases the condition of the water cannot be disregarded. More specific illustrations are: to determine whether the best maintained concentration of a corrosion inhibitor, such as sodium chromate, is 500 or 100 ppm. for a particular system; to compare the

relative effectiveness of chromate, bichromate, nitrite, and organic inhibitors; to determine whether it is permissible to decrease the concentration of inhibitor in a particular refrigeration brine, say from 100 to 50 lb. of bichromate per 1000 cu. ft.; to determine how much the concentration of chromate or other inhibitor has to be increased as the chloride content of natural waters increases; and, the effect of concentration of mineral salts in evaporative coolers, variations in pH, temperature, and aeration. Obviously there are many special corrosion tests where the final effect on the corroding medium may be disregarded; for example, the determination of the effectiveness of chromic acid anodic treatments; cathodic protection of aluminum as by a special cladding process; bichromate

treatments for zinc plate, magnesium alloys and other metals; and the comparison of corrosion inhibitive pigments such as zinc chromate and basic lead chromate.

In general it will be found in practice that most of the troublesome difficulties encountered in comparing corroded panels may be eliminated by following the outlined procedure. Of course, no system of scoring can dispense with the necessity of applying judgment to the proper weighting of the scores if they are to be used as a basis for selection of materials or treatments for a particular problem; however, the personal factor is almost eliminated in obtaining the data outlined, and these data are sufficiently complete for an experienced engineer readily to evaluate them for most specific purposes.

## Discussion

By F. A. Champion

Research Laboratories, The British Aluminum Co., Ltd.,  
Chalfont Park, Gerrards Cross, Bucks, England

I have read with interest Mr. Darrin's paper in the January, 1946, issue of the *ASTM Bulletin* on "Corrosion Criteria—Their Visual Evaluation," and wholeheartedly agree with him on the desirability of establishing uniform nomenclature for different types of corrosion.

In referring to my paper (1) on the subject, Mr. Darrin has raised some criticisms of my method, and I should be glad of the opportunity to comment on these criticisms and correct an error.

I would first make it clear that my paper was divided into two parts, the first dealing with the qualitative

method of assessment to which Mr. Darrin refers, and which depends solely on examination by the unaided eye or with the aid of binocular and monocular microscopes, while the second briefly describes an entirely distinct quantitative method of assessment of corrosion, depending on radiography, which is in course of development. The description of both methods in the same paper may have been a little confusing, but I hoped to show that if the radiographic method can be successfully developed, it will provide a valuable complementary method to the more qualitative method of

macroscopic and microscopic examination.

I am not surprised that my method should appear to be complicated, but I am sure that a very little practice would show that it is not so. The use of charts for comparison with the corroded specimen is very valuable in improving the accuracy and reliability of the observations, with the result that the seven stages given in my paper are found in practice to be more than justified. In fact, it is quite often necessary to subdivide these stages by the use of the fraction ( $\frac{1}{2}$ ), although this cannot readily be translated into words.

I feel very dubious of the value of a general scoring system such as that given in Table II of Mr. Darrin's paper, since the importance of different types of corrosion varies with the application of the metal to be considered. I have described<sup>1</sup> the

calculation, from the observations by my method of examination, of a "perforation factor" for indicating the danger of perforation by corrosion. I suggest that the calculation of such special factors from general observations by a standardized system is a more satisfactory procedure than an attempt to evaluate a single score for all purposes.

No doubt the system I have suggested, and which was developed for work on light alloys, would need considerable modification before it would be acceptable for all fields of investigation of corrosion. I feel, however, that the important feature of charts for comparison with flexible yet accurate and concise descriptions of the attack should be retained if at all possible.

<sup>1</sup> F. A. Champion, author's closure for (1), *Journal, Inst. Metals* (London), Vol. 69, pp. 498-502 (1943).

## Author's Closure

*By Marc Darrin*

Our comments regarding Mr. Champion's report are intended to draw attention to his important contribution, particularly his drawings which illustrate different types of corrosion. It would be helpful if these or similar drawings were given wider dissemination by publication in the *ASTM Bulletin*.

Naturally there are differences of opinion regarding some details as to how visual corrosion criteria should be evaluated and reported. The important thing is that *we agree that corrosion can be evaluated in a reliable and helpful manner by visual methods*. We are in substantial agreement as

to what are the essential corrosion criteria and their general types. The most important details such as differentiation between local attack and general corrosion are not subjects of disagreement.

Disregarding differences of nomenclature and wording, there are actually only two details concerning which there are important differences of opinion. The first relates to how many degrees of intensity or extent of corrosion may be readily differentiated by visual inspection. Since 1939 our laboratory has evaluated several thousand test panels. These included ferrous, non-ferrous,



and bimetallic combinations, exposed in aqueous media for long periods of time under a variety of controlled conditions. In all cases the exposed specimens were evaluated by four independent observers, one of whom was the author. It was found impossible to obtain agreement when it was attempted to differentiate between more than about four degrees for each type of attack, namely, none, slight, moderate, considerable. We do not believe that other independent observers could agree on seven degrees, much less half-degrees as Mr. Champion has suggested; nor have we found any necessity for more than four or five degrees of attack, provided the types of attack are identified.

The second difference of opinion

relates to the manner of scoring. In practice it has been found that the weightings shown in Form 1 have wide application; but, as we have previously mentioned, these weightings may be changed, or certain corrosion criteria disregarded depending on the specific application. At times it is convenient to employ the descriptive words given in Table II, but this is not an essential detail. There is some need for such descriptive words since the engineer who makes the final selection wants to know the following: first, which are the "good" panels; and, second, what is the order of merit of the "good" panels, in order that cost may be balanced against merit for any particular material of construction or manner of treatment.



## Some Metallurgical Observations with Respect to Corrosion in Distillate Wells

By M. E. Holmberg

Phillips Petroleum Company, Bartlesville, Oklahoma

THE CORROSION in distillate wells is often localized. This is not a condition peculiar to distillate wells alone; but is common in many corrosive services, including oil wells. There are a number of reasons for localized corrosion occurring, and all cases can not be explained on the same basis. One factor frequently neglected is variations within the metal itself.

Metals are often thought of as being uniform materials. Such is not the case. It should be recognized that they are neither homogeneous nor ideal. The strength differs from section to section, the composition is not uniform, inclusions are present, and the crystalline structure varies. These differences affect the performance of a metal, including the manner in which it corrodes.

Corrosion is often associated with the ends of tubing. The ends of the tubes used in distillate wells are upset so as to provide a thicker section for threading. To upset the tubes, it is necessary to heat the ends to the forging temperature. The result is that the ends differ from the balance of the tube in that they have been subjected to an additional heating and special forging operation. As the entire tube is not heated, the zone adjoining the upset is exposed to a temperature gradient. Since the crystalline structure is dependent upon the temperature to which the metal is heated, there is a great

variation in structure in this zone. The grain size of the metal heated below the recrystallization temperature is not changed. That heated just above is very fine; whereas that heated to still higher temperatures will have larger grain size, depending upon the temperature and the length of time it is above the recrystallization temperature. The net result is that where the temperature gradient existed, there is a band of fine metal that coarsens towards the upset.

Many of the tubing failures in distillate wells have been at a ring of interior corrosion near the upset. Examinations have repeatedly shown that this ring of corrosion is adjacent to the fine grained metal located in the temperature gradient just described. The location of this corrosion with respect to the changes in structure is illustrated in Figures 1 and 2.

Some people have attempted to explain this "ringworm" corrosion, as it is frequently referred to in the field, on the basis of turbulence, changes in stress due to change in section at the upset, and the heavy mill scale formed as a result of the upsetting.

It has been found that the ring of corrosion is not located any given distance from the ends. Its location varies, depending upon the length of the section heated, and the consequent location of the metal heated

just above the recrystallization temperature. The corrosion is found at both ends of the tube, whereas it would be expected to be only above the couplings if turbulence were responsible. This type of corrosion has been observed in tubing with double length upsets and invariably the ring of corrosion is adjacent to the fine grained metal. Thus it is seen that turbulence is not a cause.

Change in stress at the upset does not seem to be responsible, as "ringworm" corrosion has not been observed in tubes free from the changes in grain structure caused by upsetting. Indirectly, stress may be a contributing factor, as there is a change of physical properties accompanying the changes in structure. Tests have shown that in some cases there is an appreciable decrease in strength. As a result, the low strength metal may be stressed be-

yond the proportional limit and cause the surface scale to break loose and thus expose the metal to attack.

The excess scale is apparently not responsible for the "ringworm" corrosion, as this type of corrosion has frequently been observed in galvanized oil well tubing. Prior to galvanizing, it is of course necessary to remove all mill scale.

"Ringworm" corrosion can be avoided by eliminating the changes in structure that accompany upsetting. This is accomplished by normalizing the full length of the tube, which results in recrystallization of the metal throughout the tube's length. Some years ago "ringworm" corrosion was responsible for innumerable failures in oil well tubing in certain fields. These failures were eliminated by the use of fully normalized tubing. During the war it

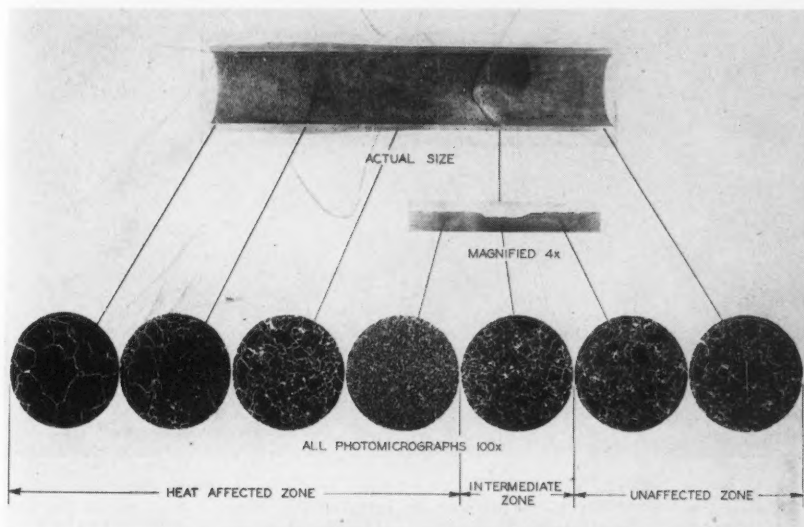


Figure 1—"Ringworm" Corrosion

was not always possible to obtain fully normalized tubing with the result that "ringworm" corrosion again has become a common occurrence where upset, but not fully normalized, tubing was used. This same type of corrosion was once common in sucker rods, but has been completely eliminated by heat treating the full length of the rods. Experi-

ence has shown that by eliminating "ringworm" corrosion, the service life of tubing can be increased.

Corrosion in tubing is not limited to "ringworm" corrosion. In general, the ends corrode more rapidly than the balance of the tube. This may be due in part to the relatively thick brittle mill scale that forms during upsetting. Another contribut-

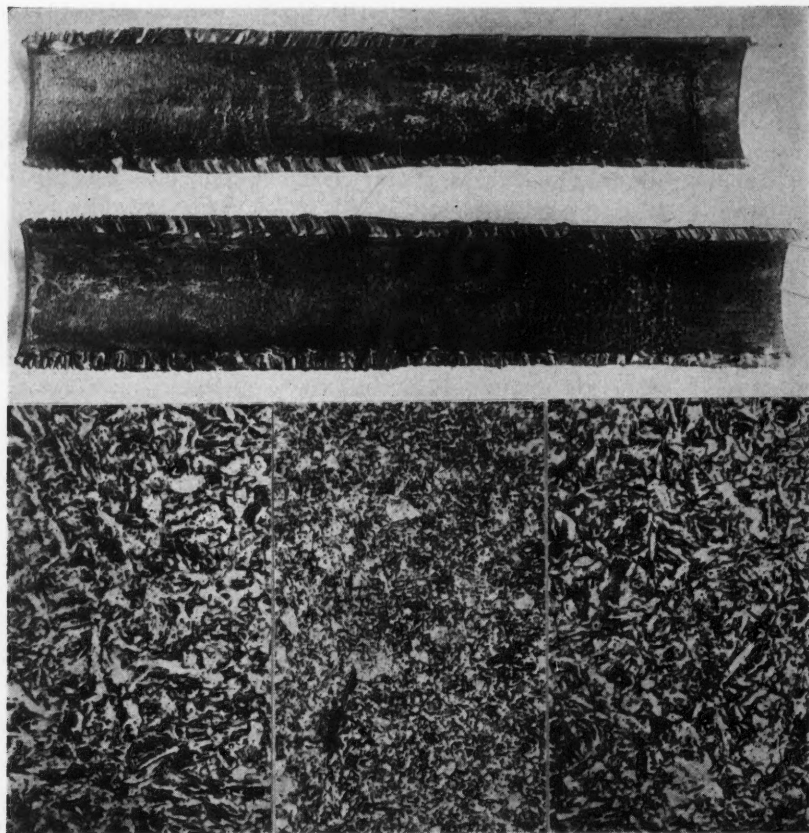


Figure 2—"Ringworm" Corrosion in N-80 tubing removed from distillate well. Structure at left is that of upset; the fine grained metal at the center is adjacent to the ring of corrosion; and the structure at the right is representative of the balance of the tube. Original magnification of photomicrographs 500X. This tubing was specified as fully normalized, but a uniform grain structure was not obtained.

ing factor may be the crushed and wrinkled structure in the upset in contrast to the straight fibrous structure in the balance of the tube. If conditions are right, the upsetting breaks up the large grain size formed during heating so that the structure in the upset will be similar to that

in the unheated portion of the tube. This is seldom accomplished, however, as heating for upsetting is not closely controlled. The result is that the structure in the upset differs from that of the tube, and there is considerable variation from upset to upset.

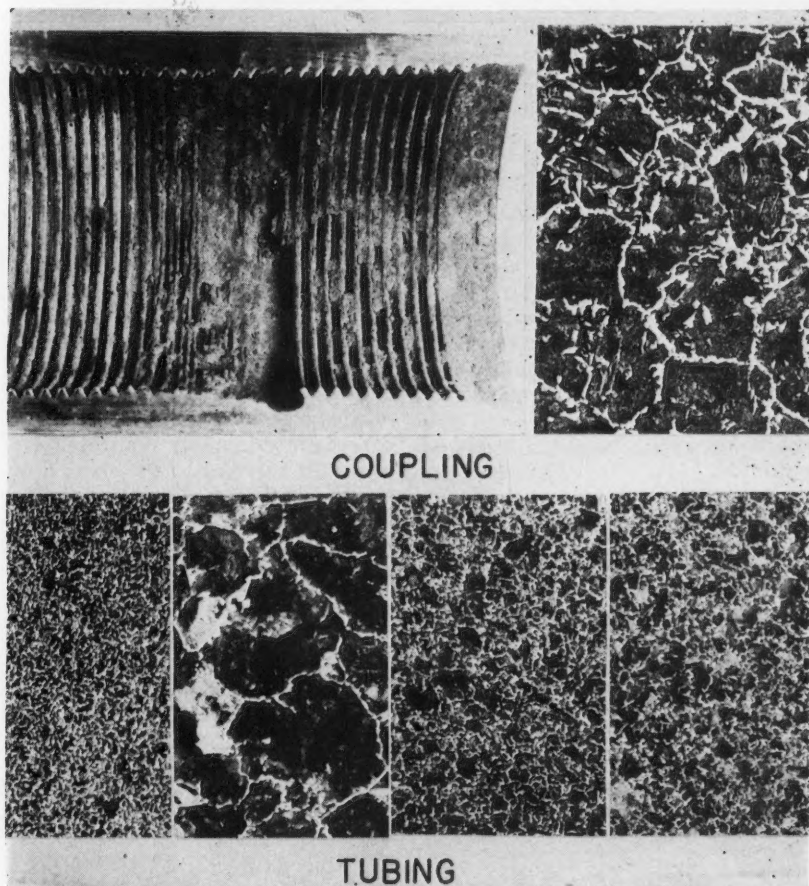


Figure 3—Corroded J-55 coupling and comparison of its structure with that of J-55 tubing to which it was attached. Tubing structures are end of upset, center of upset, fine grained metal at transition temperature, and body of tube. Magnification originally 100X.



The observations with respect to "ringworm" corrosion suggested that differences in structure might account for the interior corrosion that so frequently occurs in the exposed section of couplings. Figure 3 shows a corroded coupling and a comparison of its structure with the upset tube to which it is attached. Similar corrosion has been observed where the structures are uniform, which indicates there are other factors, such as turbulence, that contribute to the corrosion of couplings. Even though corrosion in couplings can not be eliminated by keeping their structure and composition uniform with the tubes, it is believed that by keeping them the same, the tendency for bi-metallic corrosion occurring is decreased. In some cases the differences in structure are even greater, as shown in Figure 4. Incidentally, the structures in these couplings were objectionable for reasons other than corrosion. These couplings were extremely brittle and a number of couplings have failed in

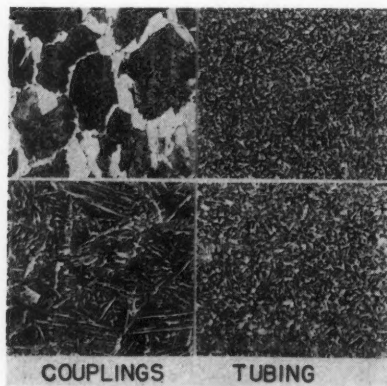


Figure 4—Structures of N-80 couplings compared with representative structures of N-80 tubing. Magnifications originally 250X.

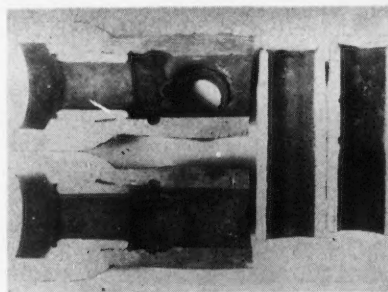


Figure 5—Corrosion in tee and hydraulic nipple.

a brittle manner in distillate wells.

Low carbon steel has often been considered more corrosive resistant in oil well service than the high carbon steels. This is not always the case and in distillate wells there have been occasions when high or medium carbon steels were more resistant than low carbon. For example, low carbon ring gaskets and other parts have been observed to corrode more rapidly than high carbon steel exposed to the same flow. Consequently one should not assume that greater corrosion resistance will be attained by decreasing the carbon content.

One of the variables that should be taken into consideration, in comparing the corrosion resistance of steels with different carbon contents, is the manner in which the carbides are present. Examinations of corroded equipment removed from distillate wells and other services have indicated that steel with a well developed pearlitic structure corrodes slower than a similar steel with a spheroidized structure. Figure 5 illustrates a section of a two-inch 10,000 psi test T-C tee with blanking plug and four-inch series 1500



companion flange welded to it. The pearlitic nipple of 0.02 percent carbon content was more corrosion resistant than the casting with spheroidized carbides and 0.32 percent carbon. Likewise a carburized ring with more than 1.0 percent carbon at the surface in the form of pearlite and cementite was more resistant than the practically carbon-free iron rings. The pearlitic flange (0.22 percent carbon) was more resistant than the casting with 0.32 percent carbon in the form of spheroidized cementite.

Mill scale is known to influence corrosion. Figure 6 illustrates a case where severe corrosion occurred at the edges of mill scale on the outside surface of a tube removed from a distillate well. On the uncorroded islands, the mill scale still remained intact and the corrosion was appar-



Figure 6—Corrosion at cracks in mill scale on outside surface of tube.

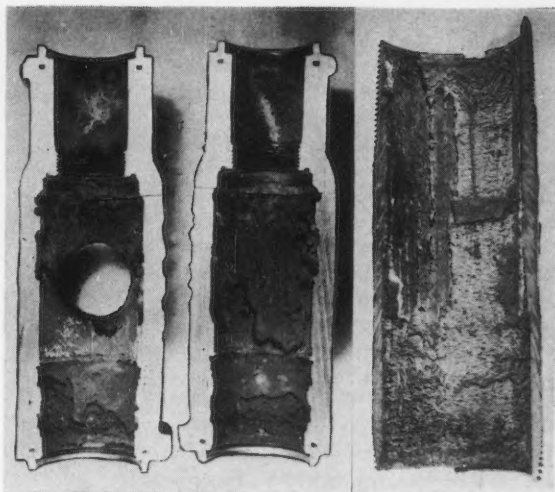


Figure 7—Corrosion in choke body and tubing hanger. Uncorroded areas were covered with an enamel-like film of magnetite and iron carbonate.

ently limited to cracks in the mill scale. This, however, is not a typical example of distillate well corrosion since it is reported to have occurred during an acidizing operation. At the same time this occurred the acid caused "ringworm" corrosion in some of the joints that had not been fully normalized. The corrosion by the inhibited acid in this well confirmed other observations that the inhibitors used in the acid for acidizing wells are not effective enough at temperatures encountered in deep wells. Tests have shown that the corrosion rates with the usual inhibited acids are very high at the temperatures existing in deep wells, so care should be taken that the acid is in contact with the tubing the shortest possible time. Some of the corrosion reported in distillate wells, especially that near the bottom pos-

sibly has occurred during acidizing operations.

Besides mill scale, the corrosion products likewise influence corrosion. Figure 7 shows a choke body with pits 0.25-inch deep and a tubing hanger with areas corroded to a depth of 0.11-inch. The uncorroded areas were covered with thin films. X-ray diffraction studies showed these films to be iron carbonate ( $\text{FeCO}_3$ ) and magnetite ( $\text{Fe}_3\text{O}_4$ ) with the iron carbonate being the larger component. Cementite, the iron carbide constituent in steel, was the only material identified by X-ray diffraction methods in the film on the corroded areas of the choke body. The hard enamel-like films of iron carbonate and magnetite on the uncorroded areas apparently protected them. The magnetite may have been part of the oxide film on the original casting, or may have been a decomposition product of the iron carbonate. The iron carbonate was undoubtedly formed by the action of the carbon dioxide in the well fluid.

At the threaded end of the tubing hanger there is a cross patch pattern. Such a pattern is often observed in metal that has been



Figure 8—Corrosion at strain lines in highly stressed pipe from flow line of distillate wells.

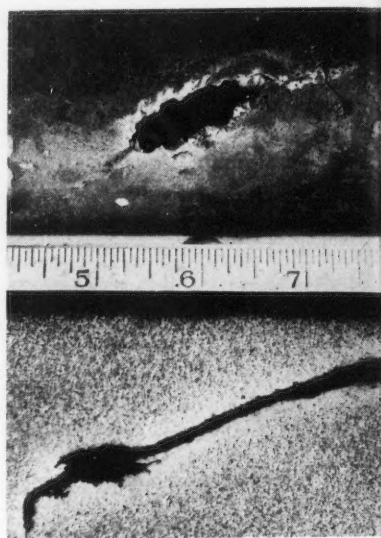


Figure 9—Washout at seam in J-55 tubing. Photomicrograph shows cross section near end of seam.

stressed above its yield point. Accelerated corrosion frequently occurs in such areas and the attack is not uniform as shown in Figure 8. Localized corrosion has been observed at highly stressed areas in threaded fittings, tubing, and flow lines.

One of the early failures in a string of tubing from a distillate well was at a "washout." This failure is shown in Figure 9. Examination revealed that the washout was located at an outside seam or lap, which is essentially a crack. A cross section near the end of the seam that accounted for the washout is also illustrated in Figure 9. Where the washout occurred, the seam extended almost through the wall of the tube. Only a small amount of corrosion was necessary before the

bottom of the seam was reached. The high pressure gas then rushed through the fine crack and within a short time cut a relatively large hole through the wall of the tube. A minor amount of corrosion, which normally would not have been serious, resulted in a bad failure because of the seam. This seam was formed during manufacturing and

its presence was more serious than the corrosion.

Variations within metal do not account for all instances of localized corrosion; but it is important to recognize that metals are not uniform and that differences in structure, composition, surface conditions, stress, and soundness of the metal tend to promote localized corrosion.

### Discussion

**By Frank N. Speller**

National Tube Company

Before this interesting discussion is concluded on the metallurgical factors affecting corrosion, I would just like to express a word of warning against too hasty conclusions. It is a very difficult matter, as has been indicated, to appraise the influence of internal metallurgical factors, against the effect of external factors, i.e., the environment, which might include mill scale. The effect of mill scale depends upon the ratio of area covered by scale to total area exposed. Experiments some time ago indicated that the corrosion losses on specimens of steel covered with various amounts of mill scale were practically the same, but if, for instance, 10 percent of the metal was bare, there was about 10 times the penetration as where all the mill scale was removed. From that, one would conclude that the best results would be obtained by removing all the mill scale.

There are usually so many factors

involved that it is often difficult to determine whether this or that factor dominates. In corrosive atmospheres, the metal composition is usually quite important; underground and where immersed in water, pitting due to contact effects is usually the controlling factor in the useful life of the metal, and its composition has comparatively little effect. There is only one exception that I recall among the low alloy steels where the metal showed a very distinct advantage both in atmospheric and under-water corrosion; that is, steel with about two and one half to three percent chromium and low in carbon seems to show both a low rate of pitting and a low average loss (about one-third of the rate of corrosion of carbon steel) both in air and water. That is rather a unique alloy, but unfortunately it is more costly and presents some metallurgical difficulties in fabrication.

**By C. K. Eilerts**

Senior Physical Chemist, Bureau of Mines, Bartlesville, Oklahoma

Those of us in the Bureau of Mines studying the corrosion that occurs in gas-condensate wells have

been trying for months to find some scientific order in the apparently factual information that has been

uncovered. The paper presented by Mr. Holmberg indicates that for him the consideration of the corrosion phenomena discussed has already been reduced to a science.

Early in our studies we wanted to investigate a number of effects which seemed to influence corrosion and to find why there was corrosion in some places and not in others, and why corrosion was very serious in one well and insignificant in another well where identical conditions for corrosion seemed to prevail. One of the conditions investigated was metal stress. The experiments performed were very simple. To prepare a sample of stressed metal, a sheet of low-carbon steel that had been formed by hot rolling was held in a vise and bent in a variety of shapes with a hammer. Coupons were sawed from this stressed steel after it had been hammered flat and resurfaced in a shaping machine. These coupons together with coupons cut directly from the hot rolled steel sheet were exposed to the cor-

rosive action of carbonic acid in an atmosphere of carbon dioxide under 200 pounds psi pressure at a temperature of 130° F. The rate at which the stressed coupon lost weight under corrosion attack was more than three times the rate measured on the specimen that had not been stressed.

Similar tests were made on steel nipples stressed at the threads. Two nipples with one-half-inch pipe threads, one male and the other female, were screwed together until the parts of the nipples in which the threads were formed were highly stressed. The nipple assembly was then exposed to the corrosive action of carbonic acid. The stressed portions of the nipples did not appear to be more corroded than the unstressed portions, but the metal loss from the entire surface of the nipple assembly was greater than had been experienced in similar corrosion tests with the same metal in a stress-free condition.



## Corrosion—News Section

### PERSONALS

**The Corrosion Laboratory** at Massachusetts Institute of Technology has been re-established with Herbert H. Uhlig in charge. Dr. Uhlig was previously engaged in corrosion studies at the Research Laboratories of the General Electric Company in Schenectady, N. Y. The M. I. T. Corrosion Laboratory is sponsored by the Departments of Metallurgy, Chemical Engineering and Chemistry.

Investigations will center primarily in fundamental studies of metal-surface reactions and methods for control of the corrosion process. The researches will be carried on largely by graduate fellows and graduate students. Courses of instruction in corrosion will be offered, as well as opportunity for thesis work in the laboratory.

Corrosion research at M. I. T. began with the investigations of Dr. Willis R. Whitney, who in 1903 published a paper outlining the electrochemical theory of corrosion. W. H. Walker, and later W. G. Whitman, with their research staffs, continued the basic investigations in corrosion now familiar to all students of the subject. It was during the 1920's that Dr. F. N. Speller cooperated in the work at M. I. T. through a grant from the National Tube

Company in Pittsburgh. The basic work made possible by this support has played a large part in laying the foundations for some of the present knowledge of corrosion control.

**A. B. Campbell**, formerly eastern representative of Hughes Brothers, has accepted the position of Executive Secretary of the National Association of Corrosion Engineers. This appointment was effective October 7, 1946.

The new secretary is a graduate in Electrical Engineering of the University of Illinois and also has the professional degree of Electrical Engineer from that school. From 1915 to 1920 he was on the faculty of the Engineering Extension Department of Iowa State College. From 1920 to 1923 he served as electrical engineer on the Iowa Board of Railroad Commissioners. He was an engineer on the headquarters staff of N. E. L. A. and the E. E. I. from 1923 to 1943, at which time he joined Hughes Brothers. He is a fellow of the A. I. E. E.

**Graver Tank & Manufacturing Company**, East Chicago, Indiana, announces appointment of Edward Welp as sales manager of water conditioning equipment. Harold C. Conners and Harold R. Fosnot have been named to head the firm's Chicago area sales activities.

**R. W. Mason, Jr.**, has joined the

Development and Research Division of International Nickel Company. He will make his headquarters at the Detroit technical section of the division. Mr. Mason will serve there as metallurgist and consultant on nickel in ferrous and non-ferrous castings.

**Scott Harrison** of the Metal Goods Corporation has been transferred from Houston, Tex., to Tulsa, Okla., where he is now manager of the Tulsa Branch of Metal Goods.

### NEW PRODUCTS

**Newest of a series** of important improvements in the design and efficiency of selenium rectifiers have been incorporated in a heavy-duty stack developed by Federal Telephone and Radio Corporation, New York, N. Y., manufacturing affiliate of the International Telephone & Telegraph Corporation. The new stack has a double-studs, center-contact construction, and 26-volt plates. Employing square-cornered plates instead of the round type, the stack is designed to mount either in a vertical or a horizontal position, affording improved and unobstructed circulation of air for plate cooling. One of the new rectangular plates more than takes the place of two of the 4 $\frac{3}{8}$ -inch diameter plates. Parallel, series or series-parallel connection permits the formation of whatever combination is needed to supply the desired load. The vibration problem has been solved by double mounts. Federal's new stack is composed of plates said to be possessing higher reverse voltage than heretofore practicable from a commercial standpoint. The plates are designed to withstand a RMS voltage of 26 volts

per plate, with a greater factor of safety and allowable reverse voltage.

**Sam Tour & Company, Inc.**, New York metallurgists and engineers, announce an extension of their facilities for research and for field service to industry. Recent developments have greatly extended the field of non-destructive examination for corrosion, as exemplified in two new instruments, the Penetron and the Probolog. With them it is possible to examine high pressure pipelines from the outside for dangerous internal corrosion or erosion, to explore ship hulls and tanks for thinning of walls that may lead to serious loss, and to examine heat exchanger and condenser tubes for detrimental conditions. Dismantling of equipment and destructive drilling of test holes can be minimized, saving time.

### GENERAL INTEREST

**Plans have been developed** for the 1947 convention of the National Association of Corrosion Engineers. The meeting will be held at the Palmer House, Chicago, April 7-8-9-10. It will feature eight symposiums on the various phases of industrial corrosion control, 32 papers by key men in the field of corrosion prevention, and 100 exhibits on latest developments in corrosion-mitigation and prevention equipment, materials, and services.

**Members of the North East Region** of the National Association of Corrosion Engineers met in New York City on June 11. John Pearson was chairman. W. Z. Friend of International Nickel Company talked on the behavior of certain metals and alloys in sulphuric acid. Charts and tables



were shown giving the rates of corrosion of the metals for various concentrations and temperatures of the acid. Data consisted of a collection of information from various investigators, with some original work. M. S. Northup of the Standard Oil Development Company presented a paper on corrosion conditions at Aruba, where salt spray from the ocean creates an unusual and very destructive corrosive action. Mr. Northup was followed by H. W. Wahlquist of Ebasco Services, Inc., who presented information on corrosion-prevention work in the Panama Canal Zone. A short business meeting also was held, during which suggestions and comments were offered for the improvement of the annual convention. About 40 members were present. Robert Pope, Bell Telephone Laboratories, 463 West Street, New York, is Regional Director of the North East Region of N.A.C.E. F. R. Arnoldy of the American Telephone and Telegraph Company, 195 Broadway, New York, is Secretary-Treasurer.

**To meet** growing membership needs and expanding field of activities, the National Association of Corrosion Engineers has recently formed a North Central Regional Division and a local Chicago Section. Members of NACE in the 13-states of this area have elected the following Regional Officers:

Chairman, Lyman F. Greve, Commonwealth Edison Company, Chicago, Ill.; Vice-Chairman, Harold A. Robinson, Dow Chemical Company, Midland, Mich.; Secretary-Treasurer, H. Anderson Ronningen, Ronningen Engineering Sales, Evanston, Ill.; Trustee, Dr. Charles A. Mann,

University of Minnesota, Minneapolis, Minn.; and Director, Dr. H. J. McDonald, Illinois Institute of Technology, Chicago, Ill.

The newly formed Chicago Section elected the following officers:

Chairman, J. P. Casey, The Crane Company; Vice-Chairman, L. G. Ranta, Chicago District Pipe Line Company; and Secretary-Treasurer, S. A. Sheridan, Armour Research Foundation, 35 W. 33rd St., Chicago 16.

The local Chicago Section, in cooperation with the Corrosion Colloquium, plans to conduct a regular program of meetings for the exchange of knowledge and ideas.

Credit is due Victor J. Payton of Chicago for his efforts as Secretary of the Organizing Committee for the North Central Regional Division.

**H. H. Anderson**, vice-president of Shell Pipe Line Corporation, has been named chairman of the Correlating Committee on Cathodic Protection, organized by American industries to assist in handling problems arising from soil corrosion to underground structures. Anderson was named in St. Louis at a meeting of representatives of the Association of American Railroads, American Gas Association, American Petroleum Institute, American Water Works Association, Bell System, The Western Union Telegraph Company, and the National Association of Corrosion Engineers.

The Correlating Committee on Cathodic Protection will undertake a program of education and assistance to industry by preparation of technical information for improving procedures for handling inter-line

problems arising from cathodic protection of pipelines, communication cables, railroad signal systems, and other buried metal structures. Cathodic protection at present is achieved by controlling electrical currents in soils adjoining buried structures to halt electrochemical corrosion of metals. The St. Louis meeting was initiated by the pipeline transportation group in the American Petroleum Institute.

**From Canada** comes information on what that country's government is doing to help fight corrosion, with establishment of a Corrosion and Corrosion Prevention Research Laboratory.

This laboratory is part of the Physical Metallurgy Research Laboratories, located in Ottawa at the Bureau of Mines. The Bureau is part of the Department of Mines and Resources of the Canadian Government. The Physical Metallurgy Research Laboratories were built during the war for the purpose of assisting the various government departments and Canadian industry in solving metallurgical problems. Until the war ended, research and investigational work was mostly for the Canadian armed forces. Now, however, greater emphasis is being placed on industrial problems.

The Physical Metallurgy Research Laboratories are divided into five sections: Ferrous, Non-Ferrous, Chemical, Mechanical and Physical. Corrosion-prevention research is an important part of the activities of the Chemical Section. All of the sections are well supplied with the most modern equipment.

The work of the Chemical Section is under the direction of Dr. R. R.

Rogers who taught a course in corrosion prevention in the Department of Chemical Engineering at Columbia University for a number of years, and who has spent some time in the chemical and metallurgical industries. The corrosion-prevention work is handled by a staff of four, including Dr. Rogers. The members of the other sections are available for consultation and assistance in their various fields. In addition, the services of the experimental foundry and plastic deformation, welding, analytical, spectrographic, photographic and oil testing laboratories and machine shop can be obtained when needed.

Although corrosion-prevention problems of almost every kind have been submitted to the laboratories, the major interest at present is in magnesium. Much time has been spent on accelerated corrosion testing of various uncoated alloys of magnesium under different atmospheric and immersion conditions, producing more corrosion-resistant magnesium alloys, investigating chemical and electrolytic coatings for magnesium, and studying the use of magnesium and its alloys for the cathodic protection of steel and other metals in fresh and sea waters.

**American Society for Metals** announces five nominees for the society's officers and trustees for 1946-1947: (1) Arthur L. Boegehold was nominated for president. (2) Francis B. Foley is vice-presidential nominee. (3) William H. Eisenman, national secretary of ASM since its organization in 1918, was nominated for reelection. (4) John E. Dorn and (5) Arthur E. Focke were nominated for two year terms as trustees.

Formal elections and induction into office will take place at the ASM annual meeting in Atlantic City during the week of November 18 as part of National Metal Congress & Exposition.

**Following is the program** for the second annual symposium on "Modern Metal Protection," held in Cleveland, Ohio, jointly by the local sections of the American Chemical Society, American Institute of Chemical Engineers, and the Electrochemical Society on September 21:

*Morning Session, Dr. C. F. Prutton, Case School of Applied Science, Presiding.*

"Fundamental Aspects of Corrosion Control," by Dr. H. H. Uhlig, Director of Corrosion Laboratory, Massachusetts Institute of Technology.

"Function of Specifications in Electroplating," By Dr. C. E. Huessner, Materials Engineer, Chrysler Corporation.

"Clad Steel Processing Equipment for Chemical and Allied Industries," by E. C. Gosnell, Colonial Iron Works Company.

*Afternoon Session, Dr. H. S. Booth, Chairman of the Chemistry Department, Western Reserve University, Presiding.*

"Plastic Coatings to Control Metal Corrosion," by Dr. S. P. Wilson, Varnish Products Company.

"Preparation of Metals for Painting," by R. E. Gwyther, Sherwin-Williams Company.

"Problems of Automotive Cooling System Corrosion Inhibition," by D. H. Green, National Carbon Company, and R. A. Willhnganz, National Carbon Laboratories.

### BOOKS

*Corrosion of Metals*, by C. W. Borgmann, C. P. Larrabee, W. O. Binder, H. L. Burghoff, and E. H. Dix, Jr. American Society for Metals, Cleveland, Ohio. Price \$3.00. A reference text on corrosion, composed of five educational lectures presented at the February, 1946, National Metal Congress. It has 192 pages, 70 illustrations, curves, tables and detailed data in 6x9-inch cloth binding, and covers the basic principles of corrosion behavior, the effect of composition and environment on corrosion of iron and steel, corrosion of stainless steels, of the light metals aluminum and magnesium, and of the copper alloys, etc.

*Metal Finishing Buyer's Directory*. Metal Industry Publishing Company, New York, N. Y. The 1946 edition of this handy buyer's guide, this directory lists alphabetically manufacturers of the equipment and supplies required by the metal plating and organic finishing industry. It is primarily intended for the use of purchasing agents and shop executives.

EDITOR'S NOTE: Members of NACE and other readers of this magazine are invited to submit items for possible use in this news section.

# **Bibliography of Corrosion Testing Methods, 1935-1945\***

*By Lorraine R. Voigt*

Corrosion Engineering Section, Development and Research Division,  
International Nickel Company, Inc., New York, N. Y.

## **ALTERNATE IMMERSION TESTS**

**Appliance for Testing Corrosion with Periodic Filling and also with Flowing Solutions.** L. P. ADAMOVICH, *Zavodskaya Lab.* 5, 1394-5 (1936).

**The Construction of a New Immersion-Type Apparatus for Testing Atmospheric Corrosion Resistance.** A. S. AFANAS'ES AND V. K. ROSTOV'TSEVA, *Tsoriya i Praktika Metallurgii* 3, 62-66 (1938).

An apparatus in which a number of specimens enclosed in a cabinet are dipped at predetermined interval into aqueous solutions and allowed to dry after withdrawal is described.

**Influence of Mode of Immersion on Corrosion Tests.** J. COURNOT AND M. CHAUSSEAN, *Compt. Rend.* 199, 1410-1 (1934).

(1), Alternate immersion and emersion; (2), immersion with the upper edge five mm. deep, the liquid being allowed to evaporate until this emerged five mm.; (3), same as (2) but with the liquid lost by evaporation being renewed; and (4), same as (3) but with the upper edge 500 mm. deep are compared.

**Alternate-Immersion and Water-Line Tests.** D. K. CRAMPTON AND N. W. MITCHELL, *ASTM Symposium on Corrosion Testing. Procedures*, 74-86 (1937).

Details of the test methods and corrosion phenomena are given.

**Corrosion of Metals.** N. GOLDOWSKI, *La Nature*, No. 2955, 540-2 (1935), No. 2957, 69-72 (1935).

New Machines for alternate immersion testing are considered.

**Practical Corrosion Tester for Chemical Engineers.** M. H. HEERON, *Chem. and Met. Eng'g.* 49, No. 2, 126-7 (1942).

An elaborate wet and dry corrosion tester is described.

**Automatic Apparatus for Corrosion Tests of Metals by Intermittent Action of Moving Liquid and Its Vapor in the**

**Presence of Air or Other Gases.** P. IVITZKII AND N. ARISTIDOS, *Zavodskaya Lab.* 4, 1113-15 (1935).

The construction and operation of the apparatus are detailed and illustrated.

**An Alternate Immersion Test for Aluminum-Copper Alloys.** R. B. MEARS, C. J. WALTON AND G. G. ELDREDGE, *ASTM Preprint* 29, 15 pp. (1944).

A control test is detailed.

**A New Apparatus for Corrosion Tests.** KH. A. SAL'KO, *Tekh Informatisionnyi Bibliograficheskii. Byull. Vsesoyuz. Nauchno-Issledovatel. Inst. pro Issledovaniyu i Proektivovaniyu. Alyuminivoy i Elektrodnoi Prom.* No. 67-8, 20-2 (1939).

A means of exposing alternately to liquid and gas.

**Testing of Corrosion Resistance of Welds.** *Schiffbau* 38, Mar. 1, 75-79 (1937).

A corrosion tester for welded samples employing intermittent immersion and testing results is reported.

## **ATMOSPHERIC AND SEA WATER EXPOSURE**

**Some Long Time Tests on Corrosion of Metals.** J. C. HUDSON, *Metaux et Corrosion* 12, No. 109-18, June (1937).

Tests carried out by the Corrosion Committee of the Iron and Steel Institute and the British Iron and Steel Federation in atmospheres at 14 localities are discussed.

**Field Tests on Ferrous and Non-Ferrous Materials.** J. C. HUDSON, *Proc. Chem. Eng. Group Soc., Chem. Ind.*, 19, 24-34 (1937).

Available experimental methods for the measurement of atmospheric corrosion are enumerated.

**The Effect of Specimen Position on Atmospheric Corrosion Testing of Steel.** C. P. LARRABEE, *Trans. Electrochem. Soc.* 85, 85-91 (1944).

Many methods of exposing atmospheric corrosion test specimens are described.

\*SOURCES OF DATA: International Nickel Company subject file of literature abstracts, Chemical Abstracts.

**Atmospheric Corrosion Testing.** H. S. RAWDON, ASTM Symposium on Corrosion Testing Procedures, 35-56 (1937).

Factors affecting atmospheric tests and procedures for handling the specimens are cited.

**Proving Ground of Marine Corrosion.** F. L. LAQUE, *Inco* 19, No. 1, 4-7 (1943).

A corrosion testing station where specimens are exposed to sea water and marine atmosphere under natural conditions is described.

**Corrosion Specimens.** J. LUCAS, *Mem. Artillerie Francaise* 16, 703-733 (1937).

Standards for sea water corrosion testing as set up by the French Commission on Corrosion are discussed critically.

### ELECTRICAL TESTS

**Method for Testing Resistance of Stainless Steels to Pitting.** S. BRENNERT, *Jernkontorets Annaler*, 119, 281-95 (1936).

An electrical method is presented.

**Local Corrodibility of Stainless.** S. BRENNERT, *Metal Progress* 31, 641-642 (1937).

An apparatus, by which variations in corrosion resistance can be measured, works on the principle that when a surface to be examined is exposed to increasing anodic polarization in relation to the solution, the degree to which polarization can be raised without inducing local attack may then be determined.

**Application of Electrochemical Measurements to Studies of the Corrosion of 18-8 Stainless Steel.** R. H. BROWN AND R. B. MEARS, *Trans Faraday Soc.* 35, Pt. 4, 467-74 (1939).

The undesirability of using single potential measurements to detect the occurrence of initial corrosion breakdowns, in cases where the polarization characteristics of the metal and solution are not understood, is emphasized.

**Electrochemical Techniques in Corrosion Study.** R. M. BURNS, *J. of Applied Physics* 8, 398-403 (1937).

Time potential measurements show whether a metal surface is in a corroding or passive state.

**Corrosion-Resistance of Nickel-Chromium Steels.** R. A. COLLACOTT, *J. of the Inst. of Engineers* 52, 121-127 (1942).

A single potential method for detection of initial corrosion is described.

**Following the Course of Corrosion of Iron within the First Time Interval by Means of the Photoelectric Determination of Iron as Sulfide.** K. DAMASCHKE AND F. LOBT, *Korrosion und Metallschutz* 16, 109-16 (1940).

A solution of sodium sulfide in 10 percent ammonia is employed with the Pulfrich photometer.

**Corrosion and Its Measurement.** A. DEMSKI, *Gas und Wasserfach* 82, 341-8 (1939).

If certain conditions are fulfilled, the progress of corrosion of a metal wire can be followed by measuring its electrical resistance.

**A Process for the Non-Destructive Determination of the Strength and Brittleness in the Case of Local and Inter-crystalline Corrosion.** W. EHRENBURG, *Korrosion und Metallschutz* 17, 19-21 (1941).

A simple electrical apparatus is described.

**Protective Films on Ferrous Alloys. Influence of Chloride Ion on Electromotive Behavior.** F. FENOVICK, *Ind. & Eng'g. Chem.* 27, 1095-1099 (1935).

The method consists of an electrometric titration wherein a chloride solution is slowly added to the solution in which the metal is immersed.

**Electrochemical Measurements for Corrosion Studies.** P. T. GILBERT, *J. of Scientific Instruments* 22, 235-237 (1945).

An apparatus for studying the behavior of pairs of coupled metals in tap water is detailed.

**A Potentiometric Method for Measuring the Corrosion Resistance of Fe-Si Alloys (ferrosilid) in  $H_2SO_4$ .** N. N. GRATSIANKII, S. M. FADUVA AND A. P. VOVKOGON, *Trudy Tsentral Lab. Zavoda "Bol'shevik,"* 112-115 (1940).

From parallel tests with ferrosilid samples by the gravimetric and potentiometric methods, the relation between the e.m.f. of the element "Pt-ferrosilid" and the corrosion stability of the alloy is determined.

**The Use of Potentiometric Methods in the Predetermination of the Corrosion of Iron Alloys.** M. L. GUITTON, *Korrosion und Metallschutz* 13, 131-44 (1937).

The corrosion resistance of an alloy in an acid can be determined by a simple potentiometric measurement, when the corrosion resistance and the electrochemical potential of a series of similar alloys have been predetermined.



**Application of Potentiometric Methods to Predict the Corrodibility of Ferrous Alloys.** L. GUITTON AND A. PORTEVIN, *Revue de Metallurgie* **34**, 564-74 (1937).

The procedure is detailed.

**Electronics and the Chemical Industry.** J. HUTCHESON, *Chem. and Eng'g News* **22**, 2170-2173 (1944).

Chemical applications of electronics, including study of corrosion, are briefly sketched.

**A Review of Methods of Electrical Prospecting in the Study of Underground Corrosion of Metals.** K. P. KOZIN, *Trudy Soveshchaniya Voprosam. Korrozii*, 179-201 (1940).

Two methods for electrical prospecting of the corroding properties of the soil are presented.

**A Simple Method of Detecting Susceptibility of 18-8 Steels for Intergranular Corrosion.** P. V. MILLIS, H. W. RUSSELL AND H. PRAY, *Steel* **108**, 2-24-41, No. 8, 26.

A small electrolytic cell is described which can determine in three minutes the susceptibility of stainless steel to corrosion.

**Examination of the Protective Value of Phosphatized Steel Sheets by Potential Measurements.** FR. MULLER AND L. HARNER, *Korrosion und Metallschutz* **17**, 229-36 (1941).

The method is detailed.

**Cathodic Reduction of Oxides on Iron Surfaces, as a Method of Estimating Corrosion.** E. A. NIKIFOROV AND L. M. GLUCHOVSKAJA, *J. Appl. Chem. Russ.* **9**, 217-224 (1936).

The amount of oxide present in the surface film of iron is determined by cathodic reduction.

**"Null" Methods Applied to Corrosion Measurements.** J. M. PEARSON, *Metal Finishing* **40**, 300 (1942).

The use of null methods to eliminate IR drops from measurements of electrode potential in the presence of polarizing current furnishes a tool for corrosion studies.

**Method of Studying Anodic, Cathodic Areas Under Cathodic Protection.** O. C. RODDEY AND L. R. SHEPPARD, *Petrol. Engr.* **15**, 174, 176, 178, 180, Aug., 1944.

A corroding unit composed of controlled anodic and cathodic areas for laboratory testing is detailed.

**Simple Method for Detecting Susceptibility of 18-8 Steels to Intergranular Cor-**

**rosion.** H. W. RUSSELL, H. PRAY AND P. D. MILLER, *Metals Tech.* **8**, T.P. 1343, 12 pp. Sept., 1941.

A rapid electrolytic test for detection of carbide precipitation is presented.

**An Electrical Resistance Method of Determining Corrosion Rates.** R. R. SEEBER, *ASTM Symposium on Corrosion Testing Procedures*, 68-73 (1937).

The specimen is a ribbon of steel whose resistance is measured without cleaning or removing.

**Method of Determining Corrosion Resistance.** H. SJOVALL, *Jernkontorets Ann.* **120**, 684-91 (1936).

The potential difference between a negative Pt electrode and an electrode of the test piece in three percent NaCl solution is measured.

**The Electrochemistry of the Rusting Process Along a Scratch-Line on Iron.** R. S. THORNHILL AND U. R. EVANS, *Chem. and Ind.* **57**, 253-54 (1938).

An apparatus is described which permits the measurement of electric currents passing around a scratch-line on iron covered with filter paper soaked in bicarbonate solution.

**Testing the Corrosion of Iron Beneath Protective Paint Films.** J. K. WIRTH, *Chem. Fabr.* **11**, 455-57 (1938).

An electrical method is presented.

**Probolog Spots Corrosion, Cracks, Holes, in Exchanger Tubes.** *Oil and Gas J.* **44**, No. 32, 121 (1945).

Irregularities in exchanger and other non-ferrous tubes are determined by probing the tube with a new instrument, the Probolog. An electric recorder registers in response to action of electrical coils pulled through each tube.

## THE HUEY TEST

**Improved Method for Determining the Corrosion Resistance of Chromium and Chromium-Nickel Steels.** C. M. JOHNSON, *Iron Age* **135**, No. 6, 12-15, 84 (1935).

A modification of the Huey method is described.

**The Huey Test for Corrosion Resistance of Welds in 18-8 Steel.** F. MEUNIER AND H. M. SCHNADT, *Arcos* **16**, 2161-2174 (1939).

Limitations to applicability of Huey's nitric acid test are cited.

**Factors Influencing the Nitric Acid Test for Stainless Steels.** J. L. MILLER, J.



Amer. Soc. Naval Engrs. **47**, 241-246, May, 1935.

A discussion of the W. R. Huey test with 66-67 percent  $\text{HNO}_3$ .

**Huey Test for Corrosion Resistance.** J. L. MILLER, Metal Progress **28**, 54-55 Dec., 1935.

The results of tests as to the reproducibility of the Huey corrosion test are reported.

**Test for General Corrosion Not Adequate for Intergranular Attack: Letter to Editor.** J. H. G. MONYPENNY, Metal Progress **44**, 104-105 (1943).

Preference is shown for the acid copper sulfate solution rather than Huey's reagent.

**Nitric Acid Corrosion Test of Stainless Weld Metal.** R. D. THOMAS, Ind. & Welding **10**, 40-42, 47 Nov., 1937.

The Huey test is reviewed.

#### IMMERSION TESTS

**Appliance for Testing Corrosion with Periodic Filling and also with Flowing Solutions.** L. P. ADAMOVITCH, Zavodskaya Lab. **5**, 1394-95 (1931).

**An Apparatus for Measuring Corrosion.** M. COHEN, Electrochem. Soc. **87**, 221-226 (1945).

An accelerated total-immersion test is reported.

**New Corrosion Testing Method.** J. CURNOT AND M. CHAUSSON, Rev. Met. **34**, 475-7 (1937).

Specimens are immersed in the liquid corroding media, and the latter are allowed to evaporate until the specimen is above the liquid.

**Apparatus for Corrosion Tests with Slowly Flowing Liquids Over Long Periods.** H. GRUBITSCH, Chem. Fabr. **10**, 83-4 (1937).

The corroding solutions run from a constant-level vessel into beakers carrying the test specimens and having an overflow.

**Corrosion Tests for Water Works Materials.** L. W. HAASE, Korrosion und Metallschutz **19**, 224-9 (1943).

Tests should be carried out by flow methods, and a number of laboratory devices for this purpose are described.

**Determination of the Corrosion Resistance of Iron and Steel.** S. JOHANSSON, Jernkont. Ann. **124**, 629-31 (1940).

Surgical Steel is immersed in 0.5 N  $\text{NaCl}$ +1.5 ml. one percent phenanthroline and colorimetric determination is made of the Fe complex.

**Method for Investigating the Rate of Corrosion in Steel.** S. JOHANSSON, Jernkontoret Ann. **125**, 599-614 (1941).

A more complete description of the method given in: Jernkont. Ann. **124**, 629-31 (1940).

**Total Immersion Testing.** R. J. MCKAY AND F. L. LAQUE, ASTM Symposium on Corrosion Testing Procedures, 87-94 (1937).

Proper procedure should provide control for temperature, aeration, velocity, etc.

**Theory of Corrosion Phenomena.** W. J. MULLER, Korrosion und Metallschutz **18**, 113-17 (1942).

Methods of testing in a stagnant liquid are considered.

**Continuous Flow Corrosion Tests of Steel Pipe.** H. S. RAWDON AND L. J. WALDRON, Proc. ASTM No. **28**, 9 pp. (1935).

Short lengths of pipe are connected by non-conducting gaskets and erected vertically, the test solution being run through by gravity from a tank. A pump is used for recirculation.

**Testing Corrosion of Welded Joints.** I. I. SIDORISHIN, Zavod. Lab. **6**, 584-588 (1937).

Immersion tests permit determination of the differences between the rate of dissolution of the basic metal and the weld.

**Practical Examination of the Corrosion Resistance of Light Alloys.** G. O. TAYLOR, Metallurgia **25**, 63-6, 101-3 (1942).

Testing equipment is described for spraying, dipping and constant immersion in salt solution.

**Apparatus for the Determination of Resistance of Alloys to Hot Corrosive Liquids.** H. THYSEN AND J. BOURDOUCHE, Met. et Corr. **13**, 37-8 (1938).

A modified apparatus for corrosion testing by the circulating pool method, whereby the corrosive liquid circulates owing to the difference in temperature at two points.

**The Total-Immersion Corrosion Test.** W. A. WESLEY, ASTM Proc. **43**, 649-660 (1934).

Reliability of the test is considered.

**Apparatus for Corrosion Tests in Gas-Saturated Solutions.** L. WETTERNIK, Korros. und Metallschutz **18**, 25-6 (1942).

A 500 cc. round-bottomed flask is filled with the corrosive liquid and circulation maintained by motion of the gas.

**Submerged Corrosion Test.** Y. YAMA-

MOTO, Bull. Inst. Phys. Chem. Res. (Tokyo) **15**, 451-80 (1936).

The influence of the testing conditions on the amount of corrosion of the immersed test piece is observed.

#### MERCURY CRACKING TEST

**The Mercury Cracking Test.** R. G. JOHNSTON, Sheet Metal Ind. **17**, 645-647 April, 1943.

Desirable features for a standard Hg test are sketched.

**Mercury Cracking Test: Procedure and Control.** H. ROSENTHAL AND A. L. JAMIESON, Metal Ind. (London) **59**, 212-15 (1941).

The results of an investigation into various phases of this test are presented.

#### THE MYLIUS TEST

**Rapid Corrosion Tests ("Mylius Number").** F. GIOLITTI, Metal Progress **31**, 175-176 (1937).

Three methods finding increasing use in Europe are described.

**The Standardization of Corrosion Tests for Aluminum.** A. V. ZEERLEDER, Schweiz. Arch. Angew. Allis. Tech. **6**, 33-40 (1940).

The "oxidizing table-salt test" of Mylius and the salt spray test are considered.

#### OIL CORROSIVITY AND BEARING CORROSION TEST

**Correlation of Laboratory Oil Bench Tests with Full-Scale Engine Tests.** C. W. GEORGI, SAE J. **51**, 52-62 (1943).

Reference oils were run in 20 laboratories in the Underwood apparatus and in the Lauson single-cylinder engine.

**Effect of Sulfur and Sulfur Compounds in Naphtha Upon Certain Corrosion Tests.** L. M. HENDERSON, M. S. AGRUSS AND G. W. AYRES, JR., Ind. & Eng. Chem. (An. Ed. **12**, 1-3 (1940).

Sensitivity of the doctor test is given.

**Processes Employed in Reconditioning Phillips' Gasoline Pipe Line.** L. A. HUGO AND G. P. JENNINGS, Oil and Gas J. **42**, 167-168, 176 (Sept. 23, 1943).

A procedure for determination of the gasoline pipeline locations, where added protection against exterior corrosion is required before actual leaks develop, is presented.

**Measuring the "Existent Corrosivity" of Used Engine Oils.** R. C. LARSON, F. A. ARMFIELD AND L. D. GRENOT, Ind. & Eng'g Chem., An. Ed., **17**, 19-24 (1945).

Use of strips coated with Pb or other metal in graduated thicknesses is described.

**Bearing Corrosion Characteristics of Lubricating Oils.** C. M. LOANE AND J. W. GAYNOR, Ind. & Eng. Chem., An. Ed., **17**, 89 (1945).

Laboratory bearing corrosion test results are compared with Chevrolet 36-hour accelerated engine test results.

**Oil Corrosion Tester.** N. MACCOULL, E. A. RYDER AND A. C. SCHLOP, SAE J. **50**, 338-45T (1942).

The test operates on the principle that the action of oil on a bearing metal at high temperature for a short time is more or less proportional to the action at a low temperature for a longer time.

**A Laboratory Machine for Investigating Corrosion of Bearings.** S. K. TALLEY, R. G. LARSEN AND W. A. WEBB, Refiner and Natural Gas Manufacturer **20**, 180 (Sept. 1941).

The apparatus is described.

**Testing Diesel Fuels.** Oel Kohle Erdoel Teer **15**, 175-6 (1939).

Test specimens for corrosive tendencies are given.

**Corrosion Test Specimens and Holders.** Oil and Gas J. **37**, 40, 48 (Dec. 8, 1938).

Procedure for studying corrosion in the oil industry is detailed.

**Copper-Strip Corrosion Test for Motor Benzol.** Oil and Gas J. **38**, 58 (March 14, 1940).

The copper-corrosion test for benzols, toluols, xylols, which is a modification of the copper strip test for gasoline is detailed.

**Corrosion Test Strips.** Business Week, No. 840, 66 (Oct. 20, 1945).

Type C Bearing Corrosion Test Strips consist of Pb plated on thin strips of Cu in different thicknesses. To determine corrosivity of engine oils, strips are attached to dip-stick of engine for one hour.

#### SALT SPRAY TESTS

**Relative Value of Accelerated Corrosion and Outdoor Exposure Tests.** W. BLUM, Monthly Rev. Amer. Electroplaters' Soc., **1936**, 8-16, May.

Accelerated corrosion tests, like the salt spray test, are valuable in determining the relative values of similar coatings, but outdoor exposure tests do not give the complete answer.

**The Salt Spray Test.** V. M. DARSEY, ASTM Bull., 1944, 31-34, May.

All important factors in the test are detailed.

**Salt Spray Testing.** E. H. DIX AND J. J. BOWMAN, ASTM Symposium on Corrosion Testing Procedures, 1937, 57-67.

Advantages and disadvantages are considered.

**Accelerated Corrosion Experiments in Sea Water.** E. DROUILLY, *Aciers Spec. Met.* 9, 490-492 (1934).

Accelerated corrosion was brought about by making tests at 40°, adding  $H_2O_2$ , using salt-spray, etc.

**Corrosion Testing of Electrodeposited Metal.** N. J. GEBERT, *Monthly Rev. Am. Electropl. Soc.* 27, 755-60 (1940).

Use of the salt spray and ferroxyl test for nickel-plated steel is discussed.

**Spray Tests.** C. E. HEUSSNER, *Iron Age* 149, 65-66 (June 25, 1942).

Work on correlating salt spray tests with outdoor exposure tests, ocean spray tests with salt spray and industrial atmosphere exposures, standardizing salt spray procedure, and studying the effect of temperature on salt spray testing is reviewed.

**Advantages and Objections to the Salt Spray Test from an Electroplater's Point of View.** A. HIRSCH, *Proc. Am. Electropl. Soc.*, 1941, 11-16.

Examples are given of inconsistent results of salt spray tests for corrosion resistance of electroplated coatings.

**Is the Salt Fog a Test for a "Poor" Nickel Plate?** G. B. HOGABOOM, *Metal Finishing* 43, No. 9, 372-373 (1945).

Tests are reviewed and recommendations made, it being better to test the Ni deposit itself rather than the usual testing of Ni-plated steel.

**A Simple Apparatus for Making Corrosion Determinations.** G. KUERNER AND W. O. LARY, *The Chemist Analyst*, 26, 93-94 Oct. (1937).

A laboratory method of determining corrosion in acids and liquors employs a filter flask, condenser, C filter tube and connecting tubes by means of which the corroding agent is maintained at constant concentration and is continuously sprayed over samples.

**Test Generators and Chambers.** W. W. MACDONALD, *Electronics* 16, No. 2, 82-86, 203-204, 207 (1943).

Salt spray devices are described.

**A Variable Cycle Alternate Immersion Corrosion Testing Machine.** C. H. MAHONEY, A. L. TARR, K. A. SKEIE, ASTM Bull., 1945, No. 133, 16-17, March.

This apparatus meets the requirements of A.S.T.M. Tentative Method B192-44T.

**The Salt Spray Test.** W. H. MUTCHER, R. W. BUZZARD AND P. W. C. STRAUSSER, *Circ. No. 530 Nat'l Bur. Standards*, 21 pp. (July 1, 1938).

Description of the salt spray test as to principles, technique and interpretation.

**Corrosion of Aluminum Alloys in Salt Spray.** W. NITZECHE, *Aluminum-Arch.* 22, 44 pp. (1939).

Forms of salt spray apparatus are critically reviewed and an apparatus to give consistent and reproducible results is presented.

**A Modified Salt Spray Test for Chromium Plated Zinc Base Die Castings.** C. F. NIXON, *Am. Electroplater's Soc. Monthly Rev.* 32, No. 11 (1945).

A modified salt spray test using a solution containing one percent glacial acetic acid in addition to 20 percent NaCl is more satisfactory than the standard salt spray test.

**Effect of Various Factors on Corrosion Tests in Moist Media of Ordinary and Semi-stainless Steels.** A. POSTEVIA AND E. HERZOG, 14<sup>me</sup> Congr. Chem. Ind., Paris, 1934, 28 pp., Oct.

Factors to be controlled in spray and alternate-immersion tests are cited.

**Accelerated Atmospheric Corrosion Test.** H. PRAY AND J. L. GREGG, *Proc. ASTM* (41), 758-65 (1941).

Air apparatus was designed in which specimens could be subjected to a cyclic process of spraying, drying, and cooling.

**Influence of Temperature on the Corrosion of Various Metals by Salt Spray.** M. SAUVAGEOT AND R. MARCHAND, *Corrosion by sea water. Meeting of the Academie Mediterraneenne*, 173-183 (March 25-27, 1937).

Experiments were made to see whether by raising the temperature an accelerated test could be obtained which would permit differentiation of the less corrodible steels.

**Accelerated Tests of Nickel and Chromium Plating on Steel.** P. W. C. STRAUSSER, A. BRENNER AND W. BLUM, *RP 724, J. Res. of Nat. Bur. Standards* 13, 519 (1934).

Salt spray and alternate immersion tests in salt spray are considered.

**Accelerated Spray Test for Determining the Relative Corrodibility of Ferrous**

**Materials.** T. SWINDEN AND W. W. STEVENSON, Foundry Trade J. 63, 173-74, 178 (1940).

A spray test using  $N/100 H_2SO_4 + N/100 NaCl$  to reproduce a cycle of changes involving wetting and drying, heating and cooling is presented.

**Practical Examination of the Corrosion Resistance of Light Alloys—II.** G. O. TAYLOR, Metallurgia 25, No. 148, 101-103 (Feb. 1942).

The "sea mist" test is reviewed.

**New Design of Humidity Cabinet for Corrosion Testing.** F. TODD, Ind. and Eng'g Chem., An. Ed., 16, 394-397 (1944).

The apparatus is described.

**Manual of Operation for Salt Spray Testing Equipment.** H. P. TROENDLY, Am. Electroplater's Soc. Monthly Rev. 32, No. 11, 1110-1114 (1945).

A manual of instructions for operating a salt spray cabinet based on ASTM designation B117-44T with recommendations by Production Engineering Sub-Committee of 0.50 cal. Metallic Belt Link Committee.

**Apparatus for Examination of Processes of Metal Corrosion.** N. A. UDALOV, Zavodskaya Lab. 5, 195-8 (1936).

Construction and operation details of "a wet chamber" for corrosion tests are given.

**The Spray Test on Metals.** Y. YAMAMOTO AND T. MORI, Bull. Inst. Phys. Chem. Res. (Tokyo) 19, 874-901 (1940).

Proper means of carrying out spray tests are given.

**Use and Misuse of The Salt Spray Test as Applied to Electrodeposited Metallic Finishes.** Electrical Manufacturing 32, 224-226 (1943).

Proper applications of the salt spray test are reviewed.

**Study of a Sprayer for Salt Spray Apparatus.** Metaux et Corrosion 14, 66 (April 1939).

The apparatus is described.

#### SOIL CORROSION TESTS

**Testing of Soils Prior to Installation of Metal Pipes.** R. R. ASHLINE, J. Am. Water Works Assoc. 30, 746-59 (1938).

Field and laboratory methods are fully described.

**Making Soil Corrosion Survey by Using Electrolytic Test.** I. A. DENISON, Oil and Gas J. 37, 96-98 (Oct. 22, 1938).

The soil is placed in a corrosion cell between two electrodes, the soil acting as the electrolyte.

**Correlation of an Electrolytic Corrosion Test with the Actual Corrosiveness of Soils.** I. A. DENISON AND A. B. DARNIELLE, J. Res. Nat'l Bur. Standards 21, 819-830 (1938).

For > 80 percent of the length of a 128 mile pipeline the electrolytic test would have predicted correctly the relative corrosiveness of the soil.

**Soil Corrosion and Pipe Protection.** T. H. GILBERT, Petrol. Engineer, 17, No. 2, 82, 84, 86, 88, 90 (Nov. 1945).

Causes of soil corrosion, soil testing, pipe protection by coating and cathodic protection are discussed.

**Electrolysis Surveys on Underground Cables.** L. J. GORMAN, Corrosion 1, No. 4, 163-177 (1945).

A summary of test methods used on power system cables.

**A Laboratory Soil Corrosion Test.** V. A. GRODSKY, J. Am. Water Works Assoc. 30, 760-6 (1938).

A test is described using discs of 0.004-inch sheet steel, suspended soils and water in which corrosion losses after 20 hours time can be studied and measured.

**Suggestions for a Better Extraction of Soil Samples for the Analysis.** C. F. HICKETHIER, Bol. Obras. Sanit. Nacion (Buenos Aires) 5, 372-5 (1941).

Rules are given for the sampling of soil the corrosive power of which is to be analyzed.

**Laboratory Tests of Cathodic Protection in Soils.** W. R. HILL, Petroleum Engr. 12, 69, 72, 74, 76 (March 1941).

The test procedure is detailed.

**Soil Corrosion Testing.** K. H. LOGAN, S. P. EWING AND I. A. DENISON, ASTM Symposium on Corrosion Testing Procedures, 1937, 95-128.

An electrical method for determining the corrosiveness of a soil toward ferrous metals is presented.

**A Comparison of Methods for Estimating Soil Corrosivity.** K. H. LOGAN AND E. A. KOENIG, Oil & Gas J. 38, No. 27, 130, 133-4, 136-8, 159-60 (Nov. 17, 1939).

Results obtained by use of various methods are considered.

**Control of Pipe Line Corrosion.** O. C. MUDD, Corrosion 1, No. 4, 192-218 (1945); 2, No. 1, 25-58 (1946).

Theory of corrosion and methods of investigation of pipeline corrosion are discussed.

**Galvanic Corrosiveness of Soil Found by Simple pH Test.** H. S. PHELP AND F. KAHN, *Elec. World* **122**, 93-96 (1944).

Voltagcs, short-circuit currents and polarization characteristics when plotted to a common base of pH correlate with galvanic corrosiveness of soil waters.

**Corrosion Coupons and Pipe Line Predictions.** W. R. SCHNEIDER, *Gas* **20**, No. 4, 39-40 (1944).

A soil test is described.

**How Soil Corrosiveness Can Be Measured.** W. T. SMITH, *Gas Age Record* **70**, 129-134, 143 (1932).

A review is given of various methods.

### MISCELLANEOUS METHODS

**Spectrographic Work in an Engineering Lab.** J. ARNOTT, *Metallurgia* **30**, 300-304 (1944).

Miscellaneous applications of the spectrograph including those for cases of corrosion are described.

**Note on the Use of Sodium-Diethyl-dithiocarbonate for Detecting the Solubility Corrosion of Metals.** ATKINS, W. R. G., *Trans. Faraday Soc.* **33**, 431-432 (1937).

The color reactions of precipitates characteristic of Zn, Cu, steel, Sn, Ag, Pb are given when an 0.1 percent solution of sodium-diethyl-dithiocarbonate is added to the liquid to be studied, which should be neutral or faintly alkaline. In the cases of corrosion-resistant bronzes and brasses, part of the solution is extracted with chloroform or carbon tetrachloride after which the pressure or absence of Cu may be detected.

**Electron Diffraction, a New Tool for Research.** C. S. BARRETT, *Metal Progress* **32**, 655-660 (1937).

Use of electron diffraction for study of surface films produced when metals corrode is considered.

**Use of Thyssen-Bourdouxhe Apparatus for Measurement of Corrosion by Solution.** P. BASTIEN, *Metaux et Corrosion* **12**, 32-35 (Feb. 1937).

Determination of corrosion speed involves measurement of loss of weight (p) in time (t) and estimation of initial specimen surface (S) and surface (S') after corrosion of time (t) giving speed to corrosion (V).

$$V = \frac{p}{S + S'} \cdot \frac{1}{t}$$

Gas evolution may also be measured.

**Development and Status of the Testing on Tension-Corrosion of Light Metals.** P. BRENNER, *Aluminum* **25**, 346-53 (1943).

Review of the method and a description of a simplified sample to give more uniform stress in testing.

**Corrosion Tests with Special Reference to Stress Corrosion.** P. BRENNER, *Papers at 1938 Convention of Deut. Ges. Metallkund*, Munich, 23-29 (June 24-26, 1938).

Two types of tests were adopted. Specimens may be bent elastically in a definite way and then held fast by a suitable contrivance, or they may be constantly strained by attaching over or under a lever arm with a weight attached.

**Stress Corrosion and Its Test.** P. BRENNER, *Korrosion und Metallschutz* **15**, 343 (1939).

The necessity of a standard test process and apparatus are emphasized. Two processes are available: corrosion with simultaneous deformation, or corrosion with simultaneous stress.

**Viewpoints Concerning a Commonly Used Corrosion Test.** S. BRENNERT, *Teknisk Litkrift*, **69**, KEMI, No. 1, 5-8 (1939).

A method of determining corrosion resistance from the quantity of hydrogen evolved or oxygen consumed is presented.

**New Methods for the Examination of Corroded Metal.** F. A. CHAMPION, *J. of the Inst. of Metl*, **69**, 47-66 (Feb. 1943).

A system of macroscopic and microscopic examination involving classification of types of corrosion is reported.

**Photographing Pipe Line Corrosion Important Part of Survey Method.** B. DAVIS, *Petroleum Engr.* **10**, 59-60, 62 (Sept. 1939).

Photographs provide a permanent corrosion record and make possible a closer study of pitting on the underside of pipe.

**Use of Solex Micrometer to Estimate the Degree of Corrosion of Metals.** K. DEVILLE, *Met. Et Corros.* **14**, 66 (April 1939).

Procedure is given.

**Application of Thermochemical Methods to Investigation on the Corrosion of Metals.** A. DARABIALSKA AND E. TURSKA, *J. Chim. Phys.* **34**, 28-36.

An adiabatic microcalorimeter and the method of applying it to the study of the heat effect of the corrosion of iron in sulfuric acid are described.



**Researches into Metallic Corrosion.** U. R. EVANS, *Chem. and Ind.* May 6, 1944, No. 19, 177.

Optical, microgravimetric and electro-metric methods of measuring corrosion are reviewed.

**Transfer of Thin Oxide Films from Metal to Celluloid.** U. R. EVANS *Iron and Steel Inst.*, 5th Rept. Corr. Comm., Spec. Rept. 21, 225-242 (1938).

A method of studying oxide films formed on metals is presented.

**The Use of Celluloid in the Construction of Apparatus.** U. R. EVANS AND R. S. THORNHILL, *Chem. & Ind.* 57, 593-595 (1938).

Use of celluloid in corrosion testing is considered.

**Assessing Wear Due to Friction and Corrosion.** P. M. FISK, *Iron Age*, 156, No. 17, 65-7 (1945).

An apparatus which tests all factors and operates all variables involved in frictional corrosion is detailed and illustrated.

**An Engineering Approach to the Selection, Evaluation and Specification of Metallic Materials—V.** H. W. GILLET, *Steel*, 114, 98, 101-102, 104, 106, 108 Jan. 10, (1944).

Special tests for corrosion and wear resistance are discussed.

**Determination of Course of Corrosion by Contact Photography.** N. GOLDOWSKI, *Korrosion und Metallschutz* 12, 108-118 (1936).

Specimens in aerated artificial sea water are illuminated and photographed at intervals.

**Colorimetric Detection of Metallic Corrosion by Means of pH Indicators.** N. GOLDOWSKI, *Korrosion und Metallschutz* 13, 128-31 (1937).

The metal surface is treated with 1 percent aqueous sodium chloride containing gelatin and an indicator.

**Corrosion Tests in Professor Palmer's Laboratory.** N. GOLDOWSKI, *Metaux et Corrosion* 12, 58-62 (March 1937).

An accelerated method employing calcium chloride for following the progress of corrosion is detailed.

**Studies on Corrosion Sensitivity.** N. GODOWSKI, et al. *Publ. Sci. Techn. Min. de l'Air*, 1936, No. 91, 1-47.

A process for testing riveted and welded joints and light metal alloys after attack by sea water is described.

**Units for Defining the Chemical Stability of Metals and Alloys.** M. M. GRATZANSKI, *Mem. Inst. Chem. Ukrain. Acad. Sci.* 5, 457-77 (1938).

A classification of metals and alloys based on depth of corrosion or deterioration in mechanical properties is proposed.

**Electron Diffraction.** E. A. GULBRANSON, *Steel* 113, 92-93 (Aug. 23, 1943).

Use of a special electron diffraction camera to study corrosion while it is taking place is explained.

**A Vacuum Microbalance for the Study of Chemical Reactions on Metals.** E. A. GULBRANSON, *Rev. Sci. Instruments* 15, No. 8, 201-204 (1944).

The technique is described.

**Accelerated Method of Determining Corrosivity of Iron and Steel.** E. I. GUROVITSCH, *Zavod. Lab.* 6, 1232-1237 (1937).

The method described depends on the fact that the number of centers of corrosion, forming on a polished iron surface exposed to damp I vapor, varies parallel with temperature and (I) and inversely with pressure ( $H_2O$ ) and is characteristic of a given steel.

**Detecting Flaws in Digesters.** R. HAAS, *Papier Fabr.* 39, 65-80 (1941). *Paper Ind.* and *Paper World* 23, 610-611 (1941).

A method employing gamma rays is presented.

**Corrosion of Copper and Alpha Brass—Chemical and Electrochemical Studies—T.P.** 1458. J. H. HALLOMON AND J. WULFF, *Metals Tech.* 9, No. 3, 18 pp. (1942).

Radio active tracer studies, among others are detailed.

**Rapid Erosion Tests Clarify Wear of Metals.** T. F. HENGSTENBERG, *Steel* 91, 21-23 (Oct. 17, 1932).

Equipment for jet tests is detailed.

**Determining Corrosion Resistance of Iron and Steel.** S. JOHANSSON, *Jernkontorets Annaler* 124, No. 11 (1940).

Means of determining dissolved Fe are presented.

**A Corrosion-Fatigue Test to Determine the Protective Qualities of Metallic Plating.** J. N. KENYON, *ASTM Preprint* No. 31 (1940).

Various mechanical and corrosion tests are reviewed.

**Application of the Reflectometric Method to the Investigation of Corrosion of Metals.** I. V. KROTOV AND V. V. ANDRUVA,



Trudy Soveshchaniya Vaprosam Koreozii, 219-30 (1940).

The method is based on the reduction of the intensity of light (determined by photoelements) reflected by the surface of the corroded elements.

**Photomicrographic Equipment for Investigating Corrosion of Metals.** A. KUFERATH, *Korrosion und Metallschutz* 13, 189-191 (1937).

Two camera attachments for taking photomicrographs and kinephotomicrographs are described.

**New Surface Test-Method in the Service of Corrosion Prevention.** A. KUFERATH, *Korrosion und Metallschutz* 11, 133-136 (1935).

A method of microscopic examination by reflected light is described.

**The Use of Electron Diffraction in Studying Corrosion.** I. R. LANDAU, *Metals and Alloys* 9, No. 3, 73-77 (1938).

Rate and character of film formation are determined by electron diffraction by taking frequent pictures.

**Testing Cutting Fluids for Corrosion Characteristics.** A. H. LLOYD AND H. H. BENNY, *Machinery* 45, 557 (1939).

A siphon drip test is explained.

**A Field Balance for Weighing Pipe to Determine Rate of Corrosion.** T. H. MARSHALL AND D. CHADE, *Petroleum Engr.* 10, 67-8, 70, 72-74 (June 1939).

A balance by which 10-foot lengths of pipe can be weighed in the field to a degree of accuracy comparable to that of the laboratory analytical balance is described.

**Corrosion Probability.** R. B. MEARS AND R. H. BROWN, *Ind. and Eng. Chem. (Ind. Ed.)* 29, 1087-91 (1937).

Corrosion probability for aluminum is investigated.

**Air Accelerated Corrosion Testing Method.** W. PALMAER, *Korrosion und Metallschutz* 12, 139-148 (1936).

Specimens covered with a film of a good conducting solution of a hygroscopic salt as  $\text{CaCl}_2$  or  $\text{LiCl}$ , are used as indicators of progress of corrosion.

**The Chemical Properties of Composite Sheets and of Welds in Them.** W. RADEKER, *Korrosion und Metallschutz* 17, 52-55 (1941).

Chemical tests for determining corrosion of clad material particularly at welds are discussed.

**Residual Stress in Caliber 0.30 Cart-ridge Cases.** H. ROSENTHAL AND J. MAZIA,

ASTM-AIME Symposium on Stress Corrosion Cracking, 14 pp. (1944).

Split-ring method of computing residual stresses is detailed.

**Measurement of Damping and Resonance (of Metals) in Corrosion Research.** A. SCHNEIDER AND F. FORSTER, *Z. Metallkunde* 29, 287-292 (1937).

The corrosion of an 11 percent Mg-Al alloy in 3 percent aqueous NaCl is followed by damping and resonance measurements.

**A New Method for Studying Cavitation Erosion of Metals.** W. C. SCHUMB, H. PETERS AND L. H. MILLIGAN, *Metals and Alloys* 8, 126-132 (1937).

The nickel tube vibratory method is detailed.

**Telltale Holes Keep Tabs on Internal Corrosion.** H. M. SPRING, *Power* 85, 102-103, (1941) March.

Use of blind holes drilled into unfired pressure vessels provides a means of checking on progress of corrosion.

**Cavitation Test of Hydraulic Turbine Model.** E. STAGE, *Teknisk Tidskrift* 37, 1003-1007 (1945).

Procedure and formulae for determining cavitation limit of hydraulic turbines are presented.

**Causes of Corrosion of Fine Copper Wires Carrying a Potential.** H. N. STEPHENS AND G. B. GEHRENBECK, *Elec. Eng'g.* 59, 357-60 (1940).

An accelerated corrosion test for two parallel bare Cu wires at a potential difference of 90 or 250 v.d.c. held under tension against the surface to be tested is presented. Amount of corrosion is estimated microscopically.

**Testing of Digesters with X-Rays.** H. SWEDENBORG, *Svensk Papperstidn.* 41, 208-214 (1938).

The possibilities of X-rays for detecting corrosion of digesters are discussed.

**Microchemistry Solves Big Industrial Problems.** K. M. SWEZEY, *Popular Science Monthly* 140, No. 4, 49-51 (1942).

Use of microchemistry to solve problems involving films of corrosion and tarnish is reviewed.

**Determination of the Corrodibility of Metal Surfaces with Iodine.** M. G. TIKHMENEV AND V. P. ZVEREVA, *Zavodskaya Lab.* 7, 679-682 (1938).

The amount of iodine used in the reaction gives the degree of corrosion and for

plated metals the degree of porosity and condition of the protective coating.

**Spark-Spectrum Study of the Corrosion of Alloys.** H. TRICHE, *Compt. rend.* **204**, 966-68 (1937).

Changes in the chem. nature of the surface can be investigated by observing high-frequency spark spectra.

**The Use of Color Photography for Recording the Results of Exposure Tests.** C. A. VINCENT, Daviss and W. Blum, *The Monthly Review* **24**, 818-822 (1937).

The record is more valuable than that obtained by black-and-white photography which does not discriminate sharply between colors or types of failure.

**Method of Measuring Corrosiveness.** J. H. WALKER, *ASTM Preprint No.* 12, 1940, 11 pp.

A device for measuring the corrosiveness of water is presented.

**Thermodynamic Considerations in the Corrosion of Metals.** J. C. WARNER, *Trans. Electrochem. Soc. Preprint* **83**, 14 pp. (1943).

The study and elucidation of corrosion reactions are discussed under two headings.

**Measurement of the Thickness of Metal Plates from One Side.** A. G. WARREN, *Instn. Elec. Engr., J.* **1939**, 91-95, Jan.

Method is applied particularly to determination of extent of corrosion, and is a conductivity method.

**Corrosion by the Impact of Falling Drops.** G. WELTER, *Engineering* **145**, 521-22 (1938).

The method of procedure and results obtained on the effect of velocity of impact of corrosive medium on different metals.

**Measuring Corrosion of Metals.** W. R. VAN WIJK, *Ind. Eng. Chem. Anal. Ed.*, **7**, 48-53 (1935).

An optical method is described.

**Spectrographic Analysis as a Means of Testing for Sea Water Damage on Metal.** S. H. WILSON, *J. Soc. Chem. Ind.* **60**, 286-8 (1941).

The procedure used for preparing a solution of the corrosion product for spectrographic analysis by the spark method is described.

**Micro-Gas Analysis Methods and Their Application to Research.** L. A. WOOTEN, *ASTM Bull.* **108**, 39-44 (1941).

Analysis of tarnish films is described.

**Rapid Test for Sensitivity towards Inter-crystalline Corrosion of Alloys of the**

**Aluminum-Copper-Magnesium Type.** E. ZURBRUGG, *Aluminum* **20**, 826-7 (1938).

The specimen is treated with  $\text{N NaCl}$  containing 10 gpl  $\text{HCl}$  and the  $\text{H}_2$  evolved during the first two hours is measured.

**Corrosion Detector.** *Ind. Equipment News* **5**, 221EN7418 (December, 1937).

A steel rod has been designed for detecting corrosive action of water inside a pressure vessel or container, in particular in steam locomotives.

**To Detect Corrosion in Boilers and Piping.** *Ind. Power* **34**, 89 (May, 1938).

A calibrated rod of known analysis is exposed in the feed water line and after a suitable period withdrawn for examination.

**Technique of Corrosion Testing.** CZOCHRALESKI, *Inst. of Met. in Warsaw. Metal Ind. (Brit.)* **49**, 347 (1936).

The degree of attack is measured by alteration in mechanical properties. Tests employed are salt spray or atmospheric exposure.

**Embrittlement Detector.** *Power* **85**, No. 13, 61 (Dec., 1941).

A device for laboratory testing of embrittling qualities of boiled water.

**Method of Obtaining Samples of Corrosive Liquids.** *Refiner* **15**, 63a (September, 1936).

A method is given for liquids which have a high gravity.

## GENERAL REVIEWS

**Design, Interpretation and Uses of Standard Corrosion Tests in Salt Solutions and Industrial Waters.** G. D. BENGOUGH AND F. WORMWELL, *Iron and Steel Inst., 4th Report of Corrosion Comm., Spec. Rept.* **13**, 213-232 (1936).

Apparatus for carrying out standard corrosion tests, giving reasonably reproducible results for comparing the corrosion rates of different metals, is detailed.

**The Principles of Corrosion Testing.** C. W. BORMANN AND R. B. MEARS, *ASTM. Symposium on Corrosion Testing Procedures*, 3-35 (1937).

A critical review with 146 references.

**Viewpoints Concerning a Commonly Used Method of Testing Corrosion.** S. BRENNERT, *Tek. Tid.* **69**, Uppl. C. Kemi, 5-8 (1939).

A discussion is given of the various precautions that must be taken in accelerated corrosion tests.

**The Application of Electrochemical Measurements to Corrosion Studies.** R.

H. BROWN, *Bull. Electrochem. Soc.*, p. 3, (Dec., 1937).

A review of the literature is presented.

**Corrosion Testing As It Was in 1915, As It Is in 1940.** R. M. BURNS, *Metal Progress*, 37, 290 (1940).

A comparison of methods is made.

**Corrosion Tests of Metallurgical Products.** R. CAZAUB, *Metaux* 9, 473-485 (1934). A review.

**Methods of Studying Corrosion of Mg and Unprotected Light Alloys.** J. COURNOT AND L. HOLM, *Compt. Rend.* 204, 1333-1334 (1937).

Report of French Aeronautical Commission on methods of studying marine corrosion of Mg and light alloys, with standards for total immersion in salt solutions, alternate immersion tests, and removal of the sample from the solution.

**Cavitation Laboratory Practice.** L. M. DAVIS, *Civil Eng'g.* 11, 148-149 (1941).

Air and water models used to evaluate turbine performance and to find portions of blades which may induce cavitation are described.

**Cavitation Testing of Model Hydraulic Turbines and Its Bearing on Design and Operation.** L. M. DAVIS, *Trans. ASME* 57, 455-462 (1935).

The work done in this field is reviewed and the results correlated.

**Methods of Testing Zinc Coatings for Corrosion.** V. N. DYATLOVA, *Korroziuja i Barba s Nei* 6, No. 3, 33-44 (1940).

A critical review.

**Examination and Determination of Quality of Electroplate.** E. EGEBERG, *Osterr. Chem. Ztg.* 43, No. 13-14, 134-7 (1940).

Accelerated and service tests for determining resistance of electroplated articles are critically reviewed.

**The Drop Test for Corrosion.** U. R. EVANS, *Rev. Met.* 33, 217-220 (1936).

A test comprising placing a drop of liquid on a metal surface provides means by which the mechanism of corrosion and its prevention can be studied.

**Testing Metals for Severe Service.** H. W. GILLET, *Metals & Alloys* 8, 101-105 (1937).

Various Testing methods are critically discussed.

**Laboratory Corrosion Tests.** N. GOLDOVSKI, *Bull. Soc. Roy. Belge. Ing. Ind.* 1939, 803-19.

A discussion of the general principles governing the choice of corrosion tests specifically for light alloys.

**Corrosion Studies in Belgium.** N. GOLDOVSKI, *Metaux et Corrosion* 14, 33-37 (March, 1939).

The organization of corrosion tests and special problems are considered.

**Corrosion Tests in the Laboratory and under Natural Conditions.** G. GUIDI, *Ind. Meccan.* 20, 112-115 (1938).

Accelerated tests for corrosion are discussed.

**Procedures for Testing Materials.** L. W. HAASE, *Kleine Mitt. Mitglied. Ver. Wasser Boden und Luft hyg.* 16, 35-36 (1940).

Methods of corrosion testing are reviewed.

**Practical Corrosion Test for Chemical Engineers.** M. H. HEEREN, *Chem. & Metall Eng'g.* 49, 126-127 (Feb., 1942).

A test apparatus developed to duplicate plant operating conditions is considered.

**Methods of Testing Corrosion and Their Respective Fields of Application.** HERZOG, *Usine* 43, No. 42, 37 (1934).

Direct optical, gravimetric, mechanical and electrical methods and indirect electrochemical methods for measuring degree of corrosion, and the conditions which influence the selection of one or the other or a combination of the methods, are discussed.

**Routine Corrosion Tests for Tinplate.** W. E. HOARE, *Sheet Metal Ind.* 13, 227-228, 374-76 (1939).

Porosity, HCl-SO<sub>2</sub> electrolytic sulfidizing and H<sub>2</sub> evolution tests are discussed.

**Corrosion Tests.** W. O. KROENIG, *Korrosion und Metallschutz* 14, 53-62 (1938).

Principles, methods and apparatus generally used in corrosion investigations are reviewed.

**Test Methods and Progress in the Stress-Corrosion Investigation at Wright Field.** H. O. MADDEN, *ASTM Preprint* 14, 20 pp. (1944).

Test methods being developed at Wright Field are described.

**Testing Welds of Light Metals.** A. MATTING AND H. KLEIN, *Warme* 62, 619-23 (1939).

Methods of testing for weldability, corrosion resistance, etc., are outlined.

**Importance of Laboratory Tests for Study of Behavior of Steel in Corrosion.**

W. J. MULLER, *Stahl und Eisen* **61**, 535-536 (1941).

Discoveries resulting from laboratory tests are cited.

**Tests of the Corrosion of Condenser Tubes**—I. Z. NAGACKA, A. WATANABE AND T. YONEYAMA, *Bull. Inst. Phys. Chem. Res. (Tokyo)* **20**, 234-46 (1941).

**Recent Developments in Corrosion Study and Control.** H. M. OLSON, *Iron and Steel Engineer*, **20**, 113 (1943).

Data and information on theory, experimental and actual problems from 50 of the best papers of the last five years are abstracted.

**Detection of Inter-crystalline Corrosion of Aluminum Alloys.** S. E. PAVLOV, *Zavodskaya Lab.* **10**, 394-6 (1941).

Several laboratory methods are presented.

**Influence of Various Factors on Corrosion Tests.** A. PORTEVIN, *Metaux et Corrosion*, **14**, 17-29 (1939).

Factors to be considered during initial conditions before test and among operating conditions during test are cited.

**Variables in Corrosion Investigations.** A. PORTEVIN, *Stahl und Eisen*, **58**, 1421-1432 (1938).

Effects of heterogeneity, surface condition, passivity, variation in testing conditions and methods of evaluating results are presented.

**Vagaries of Corrosion Testing.** F. A. ROHRMAN, *Monthly Rev. Am. Electropl. Soc.* **28**, 27-34 (1941).

Influence of variables on corrosion tests operation of tests and interpretation of results are considered.

**Principles for the Corrosion Testing of Metals.** G. SCHIKORR, *Bautechn.* **18**, 555-560 (1940).

Suitable chemical, physical, mechanical and statistical methods are discussed.

**Corrosion Testing Methods.** H. E. SEARLE AND F. L. LAQUE, *ASTM Proc.* **35**, II, 249-60 (1935).

The importance of field rather than laboratory tests is emphasized and spool tests are reviewed.

**Corrosion Research.** J. F. J. THOMAS, *Can. Chem. and Proc. Ind.*, **26**, 169-171 (1942).

Various test methods are reviewed.

**Measuring Corrosivity.** J. H. WALKER, *Proc. ASTM* **40**, 1342-54 (1940).

Loss in weight of a steel wire in a condensate-return line is used as a measure of the corrosiveness of the condensate.

**Alloys That Resist Severe Corrosive Conditions.** H. L. R. WHITNEY, *Chem. and Metall. Eng'g.* **42**, 370-371 (1935).

A discussion is given of the methods of testing corrosion-resisting materials as influenced by fabrication.

**Methods of Testing Light Metals for Corrosion.** V. S. ZORIN, *Metallurg.* **9**, No. 7, 74-80; No. 8, 87-106 (1934).

## METHODS OF CLEANING TEST SPECIMENS

**The Cleaning of Corrosion Coupons.** A. C. ALTER AND C. E. LEE, *Gas* **20**, No. 5, 49-50, 54 (1944).

A chemical cleaning method is contrasted with cathodic cleaning.

**Apparatus for Cleaning Test Coupons.** H. J. KEELING, *Gas*, **20**, No. 5, 54-6 (1944).

A cathodic method is outlined.

**Methods of Cleaning Corrosion Coupons.** C. E. LEE AND A. C. ALTER, *Petrol. Engineer* **13**, No. 10, 92, 94, 96 (1942).

Chemical vs. cathodic cleaning methods are discussed.

## INTERPRETATION AND STANDARDIZATION

**Is Corrosion Testing Ready for Standardization?** O. BAUER, *Z. fur Metallkunde*, **28**, 25-9 (Feb., 1936).

Standardization is feasible only where results are reproducible, as in stationary tests in latent, neutral water.

**Planning and Significance of Corrosion Tests.** C. W. BORGMANN, *Steel*, **102**, 42 (May 9, 1938).

Mathematical data by which corrosion results can be predicted to a degree are presented.

**The Principles of Corrosion Testing.** C. W. BORGMANN AND R. B. MEARS, *ASTM Symposium on Corrosion-Testing Procedures*, 3-35 (1937).

The desirability of standardization of corrosion tests and the difficulties involved are discussed.

**Standardization of Methods of Testing the Corrosion of Light Metals.** P. BRENNER, *Chem. Fabrik*, 486-9 (1937).

Methods for determining the resistance to sea climate and water both on shore and in the laboratory are outlined.

**Standardization of Corrosion Tests for Light Metals.** P. BRENNER, *Chem. Fabr.* **10**, 486-91 (1937).

Tests employing salt-spray, intermittent immersion, and immersion in moving liquids

are considered with respect to reproducibility of results and agreement with field tests.

**The Application of the Logarithmic Sector to Corrosion Problems.** S. A. BURKE, *Trans Faraday Soc.* 33, part 2, 309-324 (Feb. 1937).

The log sector method and its applications are described.

**Evaluation of Corrosion Tests.** R. HANEL, *Nickel Ber.* 6, 185-187 (1936).

A critical discussion on the proper evaluation of corrosion tests.

**Corrosion Testing of Water-Soluble Aluminum Cleaners.** J. C. HARRIS, *ASTM Bulletin*, No. 129, 21-27 (August, 1944).

Standardization procedure for the corrosion testing of Al Alloys is urged.

**Planning and Interpreting Corrosion Tests.** F. L. LAQUE AND B. B. KNAPP, *Corrosion and Material Protection* 2, No. 1, 17-23 (April, 1945).

Factors not usually considered are discussed.

**A Comparison of Methods for Estimating Soil Corrosivity.** K. H. LOGAN, *Oil and Gas J.* 38, No. 27, 1300, 133, 134, 136-8. 159-60 (1939) No. 17.

A statistical comparison of available methods.

**Corrosion Tests.** J. LUCAS, *Mem. Artillerie Franc.* 16, 703-32 (1937).

Standard test methods of the French Commission on Corrosion are reviewed.

**Standardizing Liquid Corrosion Tests.** R. J. MCKAY AND F. L. LAQUE, *ASTM Symposium on Corrosion Testing Procedures*, 87-94 (1937).

Control of temperature, aeration, velocity and other factors is recommended.

**Errors in Corrosion Research.** R. B. MEARS AND H. E. DANIELS, *Trans. Electrochem. Soc.* 68, 375 (1935).

Means of interpreting corrosion results by statistical analysis.

**Standardization of Salt Spray Tests.** J. POMÉY, *Metaux et Corrosion* 12, 47-51 (March, 1937).

The factors involved are discussed.

**Laboratory Equipment for Corrosion Tests.** F. B. SOLOMYANSKAYA, *Zavodskaya Lab.* 6, 1124-32 (1937).

**Standardization of Corrosion Specifications and Corrosion Tests.** F. TODT, *Chem. Fabr.* 9, 3-4 (1936).

The importance of the geometrical form of the test sample, as well as its surface area and previous history, is emphasized. Conditions for corrosion tests requiring specification are summarized.

**Fundamental Questions of Standardization in the Field of Corrosion.** F. TODT, *Chem. Fabrik*, 10, 479-482 (1937).

The theory and testing of corrosion are reviewed.

**Possibility of Standardization of Corrosion Data.** F. TODT, *Aluminum* 17, 392-3 (1935).

The possibilities of standardization information on losses by corrosion are discussed.

**Measuring Unit for Corrosion.** F. TODT, *Aluminum* 18, 133-134 (1936).

A plan for testing material, treatment of specimens and comparison of results is presented.

**Standardization in the Realm of Corrosion.** F. TODT AND W. WEIDERHOLT, *Chem. Fabrik*, 9, 178-181 (1936).

The unit of measure is considered.

**Simplification and Standardization in the Field of Corrosion Testing.** M. WERNER, *Chem. Fabrik*, 436-40 (1938).

The difficulties of standardization are discussed and fields for research are suggested.

**Standardization of Corrosion Tests in the Chemical Arts.** M. WERNER, *Chem. Fabrik*, 10, 482-486 (1937).

Scaling, boil, caustic embrittlement and other standard corrosion tests are covered.

**Standardization Work in the Field of Corrosion, Boil Test, German Industrial Standards E4852.** M. WERNER, *Chem. Fabrik*, 10, 494-496 (1937).

A tentative standard test to give a rapid measure of the corrodibility of materials used in chemical apparatus.

**The Standardization of Corrosion Tests for Aluminum.** A. VON ZEERLEDER, *Schw. Archiv. Angew. Wiss. Tech.* 6, 33-40 (Feb., 1940).

Two test procedures are given.

**Standardization in the Realm of Corrosion.** *Chemische Fabrik*, 9, 178-181 (1936).

Tentative specifications are given.

**Directions for the Standardization of Testing Conditions of Corrosion Tests.** *Z. für Metallk.* 28, No. 1, 20-22 (1936).



## Corrosion Abstracts

### BEARING CORROSION

**Oxalic Acid in Oil.** S. S. BHATNAGAR AND K. G. KRISHNAMURTHI, *Chem. Trade J. & Chem. Eng.* **117**, 746 (1945) Dec. 28; *Corr. & Mat. Prot.*, **3**, No. 4, 26 (1946) Apr.

Oxalic acid in combination with an effective anti-oxidant, like  $\alpha$ -naphthol, has proven highly beneficial. Corrosion of the bearings as well as oxidation of the oil are inhibited. Oxalic acid seems to prevent the deleterious action of oxidation products on metal surface. This may be due to the formation of a protective film of oxalate on the metal.

### BOILER CORROSION

**Corrosion of Economizer.** J. F. SLAVINSKY, *Power Plant Eng'g*, **50**, No. 5, 104, 106 (1946) May.

Bad oxygen corrosion of economizer tubes was found to result over week-end shut-downs because not enough exhaust steam was discharged from the duplex feed pump to maintain exhaust steam pressure to keep the deaerating heater operating efficiently.

**Stainless Steel for Turbine Blading—Corrosion from Contaminated Steam.** J. H. G. MONYPENNY, *Machinery Market (Lond.)*, No. 2363, 15-16 (1946); No. 2364, 17-19; No. 2365, 15-16; *Chem. Abs.*, **40**, No. 11, 3087 (1946) June 10.

The discussion deals with stainless iron corrosion from chloride, in-

creasing the resistance of stainless iron, Monel, resistance to corrosion, selection of alloy steel, physical properties at ordinary temperatures of (1) stainless iron and steel containing 16-18 percent chromium and (2) austenite steels of the 18 percent chromium-8 percent nickel type, intergranular corrosion, obscure yield point, high-nickel austenite steels, properties at high temperatures, creep tests, and fatigue limits.

**Silica in Steam—Its Causes and Prevention.** *Eng'g & Boiler House Review*, **60**, 34-38, 48 (1946) Feb.; *Corr. & Mat. Prot.*, **3**, No. 4, 24 (1946) Apr.

This is the second part of article dealing with operating experience in high-pressure, high capacity boilers of the natural and forced-circulation types. Use of potassium salts instead of Sodium for boiler water conditioning was made in an endeavor to prevent formation of silica scale. First trouble that could be attributed to Potassium was failure of hand hole Monel-clad asbestos cap gaskets. Due to potassium, the amount of iron oxide in boiler deposits also increased. Also due to increase of iron oxide, caustic attack of boiler iron increased. Chlorine was added to dilute caustic concentration.

### CATHODIC PROTECTION

**How Cathodic Protection Prevents Pipe and Tank Corrosion.** *Power Plant Eng.*, **50**, 83 (1946) June.



Theory of cathodic protection; advantages; the cathodic protection battery; preliminary steps to installation; conducting a current survey for a pipeline; test points; pipe-to-soil potential; current required for protection; ground beds; current sources; current density requirements for tanks; effect of ice on corrosion; record of protection system for a tank; costs are given.

### CHEMICAL CORROSION

**Corrosion and Hydrogen Swell in Canned Vegetables.** W. B. ADAM, Ann. Rep. Fruit Vegetable Preservation Research Sta., Campden, 1944, 37-45; J. of the Inst. of Metals and Metall. Abs., **13**, 122 (1946) Apr.

Hydrogen swells may form in canned beets during the third year of storage under normal conditions, and losses in canned stringless and runner beans may occur in cans three to four years old. Hydrogen swells rarely are found in canned peas or in any vegetables packed in plain cans. The rate of formation of hydrogen in lacquered cans is much more rapid than in plain cans. There is little, if any, solution of iron in beans in tomato sauce packed in plain cans, and this is generally true also of canned carrots and potatoes. The solution of tin in beans in tomato sauce and carrots in plain cans is severe, and there may be some stripping of the metals by oxidizing agents present in the contents. The reversal of potential, noted in canned fruits, appears to occur in canned vegetables also.

**Corrosion Problems in Gas Meters.** W. F. COXON, Gas Times, **46**, 29 (1946) Jan. 19.; Corr. & Mat. Prot. **3**, No. 4, 24, 26 (1946) Apr.

Reviews several investigations on corrosion of metals by constituents of coke-oven and illuminating gas with special reference to the work of C. M. Cawley and H. E. Newall. Evidence indicates that gas should be stripped of ammonia, and the organic sulfur concentrations should be reduced to reduce maintenance in distribution and obtain accurate service from the meters.

**Acid Corrosion of Magnesium.** G. E. COATES, Industrial Chemist, **22**, 11-15 (1946) Jan.; The Metals Review, **19**, No. 4, 8 (1946) Apr.

Purpose of the experimental work described was to measure the hydrogen overvoltage of magnesium with the object of interpreting the electrode potential of the corroding metal; to measure the corrosion rate of magnesium in various acids; and to obtain a quantitative interpretation of the corrosion rates with the help of critical current density measurements. Five references.

**Pumping Today's Liquids.** T. HUBBARD, Paper before Material Handling Soc., Pittsburgh, Dec. 17, 1945. Material Movement, **2**, 6 (1946) Feb.; Corr. & Mat. Prot. **3**, No. 4, 24 (1946) Apr.

Deals with reciprocating, rotary, centrifugal and turbine pumps. Pays some attention to pumping corrosive liquids.

**Corrosion Resistance of a Hard-Facing Alloy Suitable for Poppet Valves.** F. H. KELLY, Eaton Mfg. Co., Wil-Rich Forum, July, Nov., 1945; Ohio State Univ. Eng. Exp. Sta. News, **18**, No. 1, 32-38 (1946) Feb.

The special corrosion problems connected with the use of fuels con-

taining tetraethyl lead led to corrosion tests of various alloys for poppet valves. In tests of a high nickel chromium alloy, several tool alloys (including an exhaust valve steel) and Eatonite (nickel-chromium-tungsten-columbium), the superiority of the latter was established. Tests included partial immersion in a corrosive medium at elevated temperatures, engine tests in automotive heavy-duty and high-output supercharged engines, installation of valves with nickel chromium seat facing as well as on head proper, and hardness tests with a micro-hardness tester. The high nickel chromium alloy showed high resistance to chemical attack, but was relatively soft and wore or deformed. Its type of corrosion was intergranular. Eatonite could be made to crack, but cracking was from high stress and not intergranular. Graphs show hardness of metals at red zone temperature and corrosion resistance in controlled tests. Materials are also shown in micro-photographs for lead oxide test and after scratch tests.

**Progress in Metals—Resisting Hydrochloric Acid.** *Oil & Gas J.*, **44**, No. 50, 155-156 (1946) Apr. 20.

Materials for resisting various concentrations of hydrochloric acid are discussed. A table gives compositions and resistance for hydrochloric acid and brines. Hastelloy A and C, illium, La Bour, Contracid, Hastelloy D, pure nickel, nickel-iron alloy, copper nickel, Monel, stainless steel 25-12, Ni-Resist and nickel silvers are included. Physical and corrosion-resistant properties of Hastelloys in general are also tabulated and discussed. Sixteen corrosive media are given. Tensile strength yield,

elongation, reduction in area between 1,000 and 1,500° F. are also listed.

**The Resistance to Corrosion by Sea Water of Some Tin and Tin-Aluminum Bronzes—Paper 1022.** J. W. CUTHBERTSON, *J. Inst. of Metals*, **72**, Pt. 5, 317-342 (1946) May.

A study was made of the corrosion-resisting properties of a number of tin and tin-aluminum-bronzes to determine their suitability for use as condenser tubes. Resistance to impingement corrosion, to deposit attack, and to simple immersion corrosion in sea water was examined and compared with that of copper-nickel and aluminum brass. Effect of tin and aluminum content, aeration of sea water, and a prefilming process which retards corrosion for a time are discussed and described. A high content of tin is required for resistance to impingement. Addition of aluminum to bronzes containing 10 percent or more tin does not significantly effect impingement resistance but improves resistance to other forms of corrosion. Data on effect of aeration of sea water includes rate of deposit on 20-40 bronzes, 35-45 copper nickel and aluminum brass. Comparative tests on alloys, prepared by normal methods of casting and from degassed melts and on materials having variable and controlled grain size established the importance of homogeneity of structure and fineness of grain size in combating impingement attack.

**Burster and Isolating Discs.** F. MOLYNEUX, *Mech. World & Eng. Record*, **119**, 57-61 (1946) Jan. 18.;

Corr. & Mat. Prot. **3**, No. 4, 26 (1946) Apr.

Deals with disks used in process work for releasing pressure or where metered quantities of fluid are to be fed to reaction vessels with an important timing sequence for the arrival of the reacting fluids. The choice of material depends on corrosive or temperature conditions. Materials and their suitability for a range of applications are discussed.

**Cast Iron in the Chemical and Process Industries.** F. L. LAQUE, International Nickel Co., Pub. by Gray Iron Founders' Soc., (1945) 27 pp.

Corrosion test data from laboratory and plant tests of cast iron and austenitic iron (Ni-Resist) in several hundred chemical solutions, with a list of chemical liquids regularly handled by cast-iron pumps and valves, and a list of corrosive chemicals resisted satisfactorily by high silicon irons.

**Brine Corrosion in Refrigerating Systems.** A. J. PHILLIPS, Locomotive **46**, 4-7 (1946) Jan.; Corr. & Mat. Prot. **3**, No. 4, 26 (1946) Apr.

Presents a number of views by refrigerating engineers as well as his own. Discusses factors affecting corrosion, contamination by oxygen, metals used, stresses in pipe coils, control of corrosion, and preventive maintenance.

**Corrosion Action of Benzol Absorption Oils.** Coke & Smokeless-Fuel Age, **8**, 17-18 (1946) Jan.; Corr. & Mat. Prot. **3**, No. 4, 26 (1946) Apr.

Compares the results of an investigation reported by C. M. Cawley and H. E. Newall, 1945, with conclusions

of O. B. Wilson (Corrosion and Material Protection, April, May, July, 1945). The former and latter agree that ammonium thiocyanate is the main cause of the corrosion encountered in benzol absorption plants.

**The Internal Corrosion of Cans. Progress Report II.** D. DICKINSON, Ann. Rep. Fruit Vegetable Preservation Research Sta., Campden (Univ. Bristol), **1944**, 28-36; J. Inst. of Met. & Metall. Abs., **13**, 122-123 (1946) Apr.

De-tinned steel is attacked by boiling hydrochloric acid more readily than plain, unabraded steel. Removal of the oxide film from plain steel by abrasion results in an average increase of 38 percent in subsequent corrosion loss. A corrosivity index for fruit juices is obtained from an equation. Preliminary work shows that ripeness and variety are factors in corrosivity of fruit juices. An aqueous extract of white cherries has a corrosivity index much the same as that of a citrate buffer at pH 3-05.

**Unusual Techniques Feature the Production of Synthetic Bead Catalyst.** R. W. PORTER, Chem. & Metall. Eng. **53**, No. 4, 94-98 (1946) Apr.

Flow sheet, discussion of corrosion problems, and description of equipment used in production of the synthetic bead catalyst by Socony-Vacuum Co. are given. Activated alumina is catalytic ingredient, chemically bound in a gel of sodium silicate and an acid. A cation-anion exchange process demineralizes river water used. Key preparation takes place in silicon-42,000 gal. tanks of

tile-insulated steel. Acid-alum is key corrosive agent. One hundred and twenty-five tons of lead pipe, Worthite, Everdur, Lucite and Saran are mentioned among materials. The last two were extensively used and more satisfactory than the Worthite and Everdur.

**Continuous Tar Distillation.** R. SCOTT, Chem. Trade J. & Chem. Eng. **44**, 100-101 (1946) Feb. 16.; Corr. & Mat. Prot. **3**, No. 4, 26 (1946) Apr.

Two types of corrosion occur: one due to inorganic chlorides, the other to organic bodies, possibly higher tar acids, which are naturally occurring constituents of coal tar. Contrary to early theories which assumed that chlorides were dispersed throughout the tar, it has been proved that these inorganic salts are associated with the liquor in tars examined. Problem appears to be to remove liquor together with its chloride.

**Metal Corrosion in Salt Solutions.** I. YA KLINOV, Khimicheskaya Prom., No. 10-11, 14-18 (1944); Chem. Abs., **40**, 2097-2098 (1946) Apr. 20.

Various solutions were studied for their corrosive effect on various metals. The hypochlorite solutions corroded all of the metals tested except chromium-containing or silicon-containing cast iron, aluminum and antimonial lead. Most resistant to aluminum sulfate solutions (saturated & 10 percent) were chromium-nickel steels, chromium steels except EZh<sub>4</sub> and iron alloys. Aluminum and copper alloys were also resistant. Most resistant to 23 percent magnesium sulfate were chromium steels and chromium cast iron. Alloy

steels, including chromium-nickel and alloy cast iron, were resistant to 10 percent sodium chloride. A saturated solution of ammonium sulfate in the liquid phase did not corrode chromium-steel, chrom-nickel steel or chromium-iron. Only chrom-nickel steel and chrom-iron resisted a solution of ammonium sulfite, ammonium bisulfite and ammonium sulfate. The results of tests are tabulated.

**The Trend for Alloy-Lined Equipment in the Paper Industry.** H. A. SCHMITZ, JR., A. O. Smith Corp., Paper Ind. & Paper World, **28**, No. 2, 230-231 (1946) May.

A brief general analysis of corrosion problems in the paper industry is given. Examples of alloy-lined equipment discussed and shown are a chrom-nickel, alloy-lined acid storage tank and two chrom-nickel-molybdenum alloy-lined rotating digesters for sulphite service. Compositions are not given.

**Metals and Alloys in the Petroleum Industry.** J. H. WILSON, Jour. Inst. Petr., **1946**, 230-240, Apr.

This paper describes briefly the properties of some of the metallic materials available to the petroleum industry.

**Pressure Vessels Made with Welded Nickel Alloy Linings.** T. H. MENAUGH, Materials and Methods, **23**, 1289-92 (1946) May.

Specialized welding methods are used to line tanks with special alloys that can withstand high temperatures and pressures as well as corrosive acids.

**Corrosion Testing in a Chemical Plant.** S. W. SHEPARD, Calco Chem. Div., Am. Cyanamid Co., Chem. & Metall. Eng., **53**, No. 4, 217-218 (1946) Apr.

The importance of conducting individual corrosion tests for each specific corrosion problem in a chemical plant is stressed. A sample test record is shown. Key questions to be answered in regard to major corrosion factors (temperature, pressure, agitators, galvanic corrosion, inhibitors, etc.) are posed. One question asked is: "In stainless equipment operating under reducing conditions, are we providing sufficient air, oxidizers, or occasional passivation?" Stress corrosion cracks in a Type 347 stainless vessel are shown.

**Reactions of Aliphatic Hydrocarbons with Sulfur—Production of Olefins, Diolefins, and Thiophene.** H. E. RASMUSSEN, R. C. HANEFORD AND A. N. SACHANEN, Socony-Vacuum Labs., Ind. & Eng. Chem., **38**, 376-382 (1946) Apr.

Superheating of sulfur vapor to 700° C. as well as the handling of high concentrations of hydrogen sulfide at elevated temperatures present severe corrosion problems. Extensive tests were conducted to find corrosion-resistant alloys. High chromium type stainless steel was found superior to chrom-nickel types. Twenty-seven percent chromium steel was used extensively. High silicon steels are superior to high chromium steels, but they can only be cast and are nonmachinable. A possible solution is use of aluminum-coated or calorized steels, or aluminum containing steel alloys, perhaps also coated with aluminum. An alloy containing 20 percent chro-

mium and two percent aluminum was found to be superior to 27 percent chromium steel. Aluminum coated or calorized steels (both carbon steels and alloys) were found to be more corrosion resistant than any of the alloys just mentioned. The problem in connection with the calorized or aluminum coated steels is to obtain a coating free of surface imperfections, such as slag or oxide inclusions or pinholes. Recent improvements in the method of applying the aluminum coat may decrease the frequent failures now occurring in aluminum coating or calorized installations. The process for the reaction of the hydrocarbons is described. Equipment is shown and flow sheet given.

## COATINGS

**Baked on Plastic Coatings.** E. H. SHORT, Oil and Gas Jour. **45**, No. 14, 88-91 (1946) Aug. 10.

This article reports case histories where thermosetting plastic coatings, oven baked to tubular goods and other types of oil field equipment, have proven satisfactory in highly corrosive areas. Cases where plastic coating has reduced paraffin formation, are also cited.

**Relationship Between the Anticorrosive Properties of Paint Films and Their Pigment Content.** Fette & Seifen, **51**, 134-143 (1944); Paint, Oil and Chem. Rev., **109**, 18 (1946) Jan. 10; The Metals Review, **19**, No. 4, 8 (1946) Apr.

Pigments examined included white lead and zinc oxide, lithium and titanium dioxide, antimony oxide, litharge, red lead, zinc yellow, talc,



and others. Vehicles consisted of a variety of binders. Paints were applied to iron and magnesium alloy panels and immersed in tap water and a three percent salt solution. Effect of the so-called anti-corrosive pigments was minor in comparison with the protection afforded by the various vehicles tested.

**Metallurgical Progress and the Plastics Industry.** L. SANDERSON, *Brit. Plastics*, **18**, 40-43 (1946) Jan.; *Corr. & Mat. Prot.*, **3**, No. 4, 26 (1946) Apr.

Summary of new developments in past year. New methods of rust proofing and packaging, including spray of plastic compound, and a study of corrosion of steel by phenol at high temperatures, are discussed. Small additions of water to anhydrous phenol notably lessen the corrosion rate of carbon steel, although further additions of water increase it. This inhibiting action is attributed to the formation of a protective blue-black film found to be  $\text{Fe}_3\text{O}_4$ . Increasing the temperature to  $200^\circ\text{C}$ . increases corrosion of low carbon steel.

**Plastic Tank Coatings Resist Sour West Texas Crude Corrosion.** G. WEBER, *Oil and Gas Jour.*, **45**, No. 8, 89-90 (1946) June 29.

Successful protection against corrosion by sour crudes and salt water has been obtained through use of a plastic coating employed on the interior of oil tanks in West Texas. Results of a two-year trial of the material under extremely corrosive conditions indicate that it may prove a long term solution to many field-corrosion problems now confronting

producers. Methods of application and results obtained are discussed.

**Rust Preventive Oils. Use of Contact Angles to Study the Action of Mineral Oil Films.** G. P. PILZ AND F. F. FARLEY, *Shell Oil Co., Ind. and Eng. Chem.*, **38**, 601-9 (1946) June.

Rust preventive oils, composed of polar organic compounds in mineral oil, have been employed extensively in film applications for the temporary protection against rusting of iron and steel parts during manufacturing operations, storage, shipment and use. The condensation of moisture in droplets on such oil-coated steel parts produces a dynamic system composed of water, oil film and metal. A study of the contact angles formed by such a system where a drop of water rests on a horizontal oil-coated steel panel has established a relationship between contact angles and rust preventive ability. A mathematical analysis of the forces involved in the spreading of a water drop on a rust preventive oil film has shown that the equilibrium surface tensions of the water and oil and their interfacial tension are the major factors determining the magnitude of the contact angle. These findings are in agreement with the theory of rust prevention which postulates orientation of the polar organic additive at the oil-metal interface, and establishment thereby of a barrier to normal mode of entry of the causative agents of rusting—oxygen and water. Contact angles were measured by a microscope fitted with a goniometer eyepiece; they have been employed in determining that solubility of water is of prime importance among the physical properties of rust-preven-



tive additives and have found application in controlling plant production of rust-preventive oils.

**Action of Antifouling Paints. Solubility and Rate of Solution of Cuprous Oxide in Sea Water.** J. D. FERRY AND D. E. CARRITT, Wood's Hole Oceanographic Inst., Ind. and Eng. Chem., **38**, 612-7 (1946) June.

The solubility of cuprous oxide, the most commonly used antifouling toxic, has been measured in oxygen-free sea-water. It is proportional to the hydrogen ion concentration and agrees with calculations from thermodynamic data, assuming that the dissolved copper exists as the complex ions  $\text{CuCl}_2$  and  $\text{CuCl}_3$ . The rate of solution of cuprous oxide in sodium chloride-nitrate-borate buffers is proportional to the hydrogen ion concentration, and is a linear function of the square of the chloride ion concentration at constant ionic strength. It is concluded that the dissolution occurs principally by a process whose rate determining step is the formation of  $\text{CuCl}_2$ , together with a small contribution from a process which does not involve chloride ions.

**Properties of Saran Coating Latex.** G. W. STANTON AND W. A. HENSON, Dow Chem. Co., Paper before T. A. P. P. I., N. Y. C., Feb. 27, 1946; Corr. and Mat. Prot., **3**, No. 4, 6-12 (1946) Apr.

Uses, properties and manufacturing process for Saran coating latex are described. Order of preference for metals processing and handling Saran lattices is: stainless steel, chromium, tin, bronze, brass, nickel and aluminum.

**A Protective Chemical Treatment for Tinplate.** R. KERR, J. Soc. Chem. Ind., **65**, No. 4, 101-104 (1946).

Immersion of tinplate for 10-60 seconds at 70-80° C. in a solution containing eight g. sodium dichromate, 20 g. sodium phosphate, 20 g. sodium hydroxide and three g. of a penetrating agent Dispersol L or Teepol per liter, and rinsing in water, causes formation of an invisible film preventing blackening by sulfur-containing foods and retarding rusting in moist air. Exposure, humidity chamber and cannery tests are discussed. No difference was found between treatment before or after fabrication. Treated tinplate: (1), improves adhesion of external air-drying lacquers; (2), does not affect adhesion of fruit or sulfur-resisting lacquers; and (3), impairs adhesion of phenolic-resin meat lacquers. No effect of tin thickness was noted in protection against sulfur-blackening, but the treatment was most advantageous on thin plate for rust prevention.

**The Effectiveness of Paint in Suppressing Galvanic Corrosion.** G. W. SEAGREN, G. H. YOUNG, Mellon Inst., and F. L. LAQUE, International Nickel Company, Corrosion, II, No. 2, 67-77 (1946) June.

Experiments at Kure Beach show that presence of galvanic or stray electrical currents from external sources means that painting only the surfaces to be protected may be dangerous, in fact may even cause acceleration of corrosion at area of paint discontinuity. Safest practice is to paint both anodic and cathodic areas with the best alkali-resistant paints or coatings available, taking care to avoid pinholes, uncoated

edges, faying surfaces and similar foci for localized galvanic attack. Data and illustrations of copper-steel couple test panels, and effect of painting cathodic areas at Kure Beach, are given.

**Protection of Iron and Steel.** U. R. EVANS, *Metal Ind. (Lond.)*, **67**, No. 8, 114-118 (1945).

Commercial applications of non-ferrous metal coatings on new or rusted structures are discussed. Proposed methods are: (1), spraying by aluminum followed by ordinary painting; and (2), paint richly pigmented with zinc to constitute a galvanized coat. In some instances such coats make contact with the steel by partial reduction of rust to metal, thereby providing conducting bridges. It is impractical to load linseed oil with sufficient zinc dust even if other pigments are omitted; therefore plasticized polystyrene solution containing zinc dust up to 95 percent zinc by weight which can be brush applied, and a commercial chlorinated rubber paint possessing the required zinc content are substituted. Such paints reduce or prevent corrosion fatigue by mechanical exclusion of the corrosive or by electrochemical protection. Laboratory tests show that such paints on rusty steel give cathodic protection in sea water.

#### CONSTRUCTION MATERIAL

**Cemented Steels—A New High-Strength Powder Metallurgy Product.** F. P. PETERS, *Materials & Methods*, **23**, No. 4, 987-991 (1946) Apr.

Sinteel "G," manufactured by American Electro Metal Corp., is a steel cemented with copper alloy, produced by infiltrating a porous

steel skeleton with molten copper alloy. No subsequent coining operation is required. Final product is pore-free and has tensile strength of 50,000 to 100,000 psi. It may be quenched-and-tempered or case-carburized, and has also the precipitation-hardening properties of iron-copper combinations. By heat treating, tensile strengths up to 170,000 psi are obtained. An interesting characteristic is special amenability to brazing without external application of brazing alloy, since these steels carry their own "brazing alloy." Production technique, properties, and uses are discussed. Microstructures are shown, together with special device for applying process to very large or complex parts. Table and graph include iron-copper as well as steel-copper combinations. Materials are close to absolute density and are more machinable than porous products. Size ranges are from three ounces to 20 pounds.

**Corrosion of Steel.** J. JOHNSTON, *Corr. & Mat. Prot.*, **3**, No. 3, 9-12 (1946) Mar.

Statement of U. S. Steel Corp. for a general guide. Comparisons of corrosion resistance of copper steel with iron and plain carbon steels, and of Cor-Ten and other low-alloy, high-strength steels with that of copper and carbon steels are drawn. Graphs show influence of copper in retarding corrosion of steel, time-corrosion curves of low-carbon plain steel sheet, low-carbon copper steel sheet and U.S.S. Cor-Ten in an industrial atmosphere and a marine atmosphere (Kure Beach). Mention is made of the fact that certain alloying elements, particularly nickel, are relatively more effective in enhanc-

ing corrosion resistance in marine than in industrial atmospheres.

**Electrolytic Corrosion of Fourdrinier Wire Seams.** Paper Indus. & Paper World, **28**, No. 1, 53-56 (1946) Apr.

Article prepared by staff of research laboratory of Lindsay Wire Weaving Co. on galvanic corrosion of Fourdrinier wire seams. Dissimilar metals are the silver-brazing alloy and the material from which the wire cloth is manufactured, either brass or bronze. Another example involved the use of stainless steel stitching wire for seams in coarse mesh wires or in repairing breaks in these wires. The brass shute wires are strongly attacked where the steel wire contacts them. Laboratory tests and mill observations are in process, analyzing causes and finding means to prevent corrosion of this type. Wires of bronze construction are more readily attacked than ones with brass shute. Contents of water are being closely watched. Variables under consideration in a laboratory test involving use of electrolyte are: type of solder alloy, type of cloth material, nature of electrolyte, temperature at which cell is held during duration of test, degree of aeration and agitation, duration of exposure. Corroded wire is shown.

**Modified Aluminum-Copper Alloys.** S. A. J. SAGE, Mech. World & Eng. Record, **119**, 207-208 (1946) Feb. 22; Corr. & Mat. Prot., **3**, No. 4, 22 (1946) Apr.

In Y-alloy it was found that nickel improves strength at high temperatures, and the small addition of magnesium improved the properties of the aluminum-copper-nickel alloy.

Its outstanding properties are strength at high temperature, good elastic properties, corrosion resistance and high thermal conductivity. Duralumin, under some conditions, has been known to suffer intercrystalline corrosion. The longer the delay between heat treating furnace and quenching tank or the slower the quenching action of the cooling medium, the more prone was Duralumin to intercrystalline corrosion. To improve corrosion resistance of Duralumin, cladding with layers of pure aluminum has given good results.

**The Uses of Wire Ropes.** J. T. SETTERMAN, Paper before Frederick Smith Staff School, Wire Ind., **13**, 41-43 (1946) Jan.; Corr. & Mat. Prot. **3**, No. 4, 26 (1946) Apr.

Deals with history, uses and various types of wire rope. Discusses briefly the corrosion of wire rope in salt mines.

**PIPE LINE CORROSION**  
**Anaerobic Corrosion of Steel Pipe Due to Nitrite.** D. H. CALDWELL AND J. B. ACKERMAN, J. Am. W. W. Assoc., **38**, 61-64 (1946) Jan.; Corr. & Mat. Prot., **3**, No. 4, 24 (1946) Apr.

Gives results of investigation of the cause of rapid corrosion of steel water main at a Navy station in California, delivering water from two deep wells. Analyses of the water showed high nitrate content, which in the absence of dissolved oxygen served as a cathodic depolarizer in the corrosion reaction and resulted in appreciable concentrations of nitrite, ammonia and ferrous hydroxide. Describes steps taken to a satisfactory solution of the problem.

**Protecting Underground Pipe Lines.** J. C. STIRLING, Stanolind Pipe Line Co., *Oil Weekly*, **122**, No. 4, 64+ (1946) June 24.

Successful methods for economically combating external corrosion of underground pipelines are discussed.

**Internal Pipe Line Tool Developments.** A. M. HILL, *Oil Weekly*, **122**, No. 4, 81+ (1946) June 24.

Describes and illustrates various pipe-line scrapers and go-devils in use by pipeline companies today.

**Anaerobic Corrosion of Buried Iron Pipes.** O. B. WILSON, *Water & Water Eng.*, **48**, 594-598 (1945); *Chem. Abs.*, **40**, 2431 (1946) May 10.

Surface-reducing bacteria are shown to be more active in the presence of organic material found in the soil. Iron pipes should, therefore, be protected adequately with the proper coating to prevent the hydrogen sulfide formed from reacting with ferrous ions going into solution. Experiments with pipes properly coated showed no corrosion after two years. Sulfate-reducing bacteria are active in either a neutral or a slightly alkaline soil, the apparent pH limits being 7.0-7.8.

**Spot Reconditioning Pipe Lines.** W. H. T. THOBUEHILL, Wailes Dove-Hermiston Corp., *Petr. Eng.*, **17**, No. 9, 228-9 (1946) Je.

A method for cold spot-reconditioning of pipelines is described. The steps recommended are: (1), cleaning; (2), drying; (3), application of heavy bodied coal-tar base coating; (4), wrapping with 12-ounce tar

saturated fabric or Fiberglas wrapper; (5), application of second coat of coal-tar coating; and (6), wrapping with 15-pound coal-tar saturated asbestos felt.

**Measurement of Cathodic Protective Currents in Submarine Pipe Lines.** W. RYLAND HILL, University of Washington, *Petr. Eng.*, **17**, No. 6, 168 (1946) Mar.

A method is presented and explained in detail with graphs and charts showing how the minimum protective current density on a submarine pipeline can be calculated from two electrical measurements: determination of the current at the shore end of the line, and the voltage drop between the shore and sea ends.

## REFINERY CORROSION

**Study of Corrosion Pattern in Still Tubes Results in Reduction of Metal Losses.** W. F. KRAMER, Toledo Refinery, Pure Oil Co., *Nat. Petrol. News*, **38**, No. 1, R-17-18, 20, 22 (1946) Jan. 2.

Experiences with metal loss in cracking-still tubes at one refinery are described. Rate of internal corrosion is related to position of tubes in furnace. A method of plotting annual measurements of inside diameters of the tubes is described with examples. Indications of the effect of temperature, turbulence, and coke deposition, dependent upon position of the tubes, are given. The relative resistances of the several alloys (chromium steels) and plain steel, as well as their annual penetration rates, may be determined from the patterns.

Re  
Alloy  
the  
MOR  
Paper  
N. Y  
J., 44  
Tran  
(1946  
Re  
differ  
being  
water  
the  
F., "  
take  
fur  
Below  
electr  
gene  
data  
meria  
ide g  
inclu  
stain  
steel  
bron  
iron.

Sta  
Indu  
nois  
ern  
Wor  
Petr  
Apr.  
A  
devo  
its p  
refin  
types  
parti  
Men  
12 cl  
over  
are c

**Resistance of Nickel - Containing Alloys to Corrosives Encountered in the Petroleum Refineries.** B. B. MORTON, International Nickel Co., Paper before A.S.M.E., Ann. Mtg., N. Y., Nov. 26-29, 1945; Oil & Gas J., **44**, No. 31, 73-74 (1945) Dec. 8; Trans. ASME, **68**, No. 3, 229-235 (1946) Apr.

Refinery corrosion possesses two different identities, the dividing line being the temperature level at which water is no longer present. Above the arbitrary temperature of 500° F., "dry" corrosion is considered to take place due to the action of sulfur and also some organic acids. Below this temperature "wet" or electrolytic corrosion takes place. A general solution is given. Corrosion data from a study of alloys in isomerization units in hydrogen chloride gas and acid are tabulated and include Monel, nickel, Inconel, 18-8 stainless steel, 18-8-molybdenum steel, Hastelloy B, silver, copper, bronze, Ni-Resist, mild steel and cast iron.

**Stainless Steel in the Petroleum Industry.** J. S. EWING, Carnegie-Illinois Steel Div., Paper before Western Petrol. Refiners Assoc., Fort Worth, Texas, March 26, 1946; Nat. Petrol. News, **38**, R-243-246 (1946) Apr. 3.

A large portion of the article is devoted to stainless "W" alloy, and its potential uses in the petroleum refinery industry. Uses of other types of stainless are also discussed, particularly stainless bubble trays. Mentioned frequently are 18-8 and 12 chromium stainless. Use of weld overlays, and cold end applications are covered.

**Technical Service Pays Its Way.** Nat. Petr. News, **38**, No. 21, R-403-407 (1946) June 5.

Even in smaller refineries new functions are being found for the technical groups first organized as a liaison between professional engineers and the plant operating force. Data for this article was secured through studies made by NPN Technical Section's representatives of seven refinery organizations.

**Economic and Successful Operation Obtained at HF Alkylation Plant.** J. A. SCOTT AND R. M. COOPER, Sinclair Refining Co., Oil & Gas J., **44**, No. 47, 204+ (1946) Mar 30.

Report of equipment after 20 months of continuous operation includes mention of replacement of much of steel material by alloys and alloy trim. Valve combinations tried included soft-steel plugs, Monel-lined plugs, and stellited plugs, plus Monel-lined bodies. The latter were finally adopted.

## SURFACE TREATMENT

**German Low Temperature Phosphating of Metal.** Chem. & Eng. News, **24**, 1126-1127 (1946) Apr. 25.

Developments in both Europe and U. S. on phosphating for corrosion protection are briefly sketched. The Metallgesellschaft Akt. Ges. of Frankfurt carried out experimental work publicized in the technical press, e.g., by L. Schuster and R. Krause [Korrosion und Metallschutz, **20**, 153-161 (1944)]. This company was mainly responsible for introducing American methods, including bonderizing, into Europe. Cold bonderizing, introduced in 1941, was quickly adopted on a large



scale, not only for rust-proofing metals but in stressless forming and shaping of steel parts, such as in deep drawing. These authors based their work on previous investigations of Eberley, Gross and Crowell [J. Am. Chem. Soc., **42**, 1433 (1920)], who studied the solid-liquid phase in the system zinc-oxide-phosphorous-pentoxide-water at 25° and 37°. Chief factors stressed are mentioned.

**Sodium-Hydride Descaling and Desanding of Ferrous Castings and Forgings.** Ind. Heating, **13**, No. 5, 796+ (1946) May.

Set-up for sodium-hydride descaling and desanding in a plant manufacturing oil-pump bodies and parts of gray iron is shown and described. Charging a soaking pit in the Duquesne Works of Carnegie-Illinois Steel Corp. is also shown.

**Chemical Cleaning of Refinery Equipment:** W. J. DAVIS Petr. Eng., **17**, 51-4 (1946) June.

The chemist now has inhibitors and wetting agents to help in cleaning machinery without dismantling. Applications of these compounds are discussed.

**Hard-Surfacing Light Metals.** W. C. REID, Metallizing Eng'g Co., Modern Metals, **2**, No. 3, 6-7 (1946) Apr.

All aluminum and magnesium alloys can be easily and inexpensively hard-surfaced to any required depth by spraying with carbon steels, stainless steels, nickel, Monel, Nichrome, bronze, alloys, and, for certain bearing uses, with babbitt. The bond is mechanical, produced by roughing with a special tool, and ranges in shear from 3,000 to 8,000

psi. When applying brasses and bronzes, a very thin coating of stainless steel should be applied first. Surface qualities include a marked tendency to work harden, a coefficient of friction as much as 25 percent less than the same material in solid form, and an ability to absorb oil to such an extent that a sprayed metal bearing surface is comparable to the best oil-less bearings. One of the earliest applications was that of stainless or high carbon steel to aluminum patterns subjected to excessive abrasion. Inserts of Monel, nickel and other materials became common. The spraying equipment and pounds of material, including nickel, Monel, and stainless steel, sprayed per hour, are described and tabulated.

**Guide Ropes.** J. Mining, **226**, No. 5772, 267 (1946) Apr. 6.

Types of wire ropes preferred in Great Britain are described. Round, half-lock and tubular guide ropes are shown, and their construction discussed. Scale removal is accomplished by immersion in muriatic or sulphuric acids. Tensile stress, wire drawing process, slip action of material are briefly mentioned.

**Hard-Facing Materials to Improve Product Performances.** A. C. CAPE, Coast Metals, Inc., Prod. Eng'g, **17**, No. 2, 134-137 (1946) Feb.

Hard-facing alloys, their application, and properties of deposits, are tabulated, classified and discussed in detail, with numerous illustrations. Among nickel alloys, Eatonite, containing 40 percent nickel, is mentioned. Hard-facing alloys are classified in four groups: (1), wear re-



sistant; (2), wear resistant and impact resistant; (3), wear and impact resistant at high temperatures; and (4), temperature and corrosion resistant.

**A Metallographic and Crystallographic Study of the Growth and Structure of Anodic Films on Aluminum.** P. LACOMBE AND L. BEAUJARD, *Etudes sur les Aspects des Pellicules d'Oxydation Anodique formées sur l'Aluminium et ses Alliages*, 1944, 13-89; *J. Inst. of Met. & Metall. Abs.*, **13**, 53-54 (1946) Feb.

That the rate of growth of the film is determined by the orientation of the crystal upon which the film grows was confirmed by measurement of the thickness of the film by optical means.

**Protection of Steel from Corrosion by Chromium Diffusion.** H. KALPERS, *Korrosion und Metallschutz*, **18**, 236-238 (1942); *Brit. Abs.*, BI-Chem. Eng'g & Ind. Inorganic Chem., Including Metall., Jan., 1946, 30.

The B.D.S. "Inkromieren" process of Becker et al. (b., 1942, I, 155) is described. Mild steel is treated with chromium chloride vapor at a high temperature, whereby iron is replaced by chromium at the surface of the steel; and an alloy zone in which the chromium content decreases gradually with depth from a surface value of 33 percent is produced by diffusion. The outer part of the diffusion zone, in which the chromium content is less than 13 percent, is not attacked by, e.g., nitric acid. Low carbon steel, preferably with an ultimate stress of 30-35 kg. per mm.<sup>2</sup>, must be used. The alloy zone is mechanically inseparable

from the steel. The process can be applied to steel plates and castings.

**A Micrographic Study of Sections of Anodic Films on Aluminum-Magnesium Alloys.** P. LACOMBE AND L. BEAUJARD, *Etudes sur les Aspects des Pellicules d'Oxydation Anodique formées sur l'Aluminium et ses Alliages*, 1944, 59-72; *J. Inst. of Met. & Metall. Abs.*, **13**, 53 (1946) Feb.

Methods are described for measuring the thickness of anodic films. In applying method of direct measurement (under microscope after polishing a section) to the study of aluminum-magnesium alloys, changes in the thickness and structure of the film close to crystal boundaries and particles of precipitate, which could be correlated with the heat-treatment and structure of the samples, were observed.

Changes were noted in the films when an examination of their surfaces was made. The results are discussed from the point of view of the theory of precipitation, and it is suggested that the technique may be a valuable one in studying precipitation phenomena.

## WATER CORROSION

**Chromate Corrosion Inhibitors in Chloride Systems — Rate of Consumption of Chromate.** MARC DARIN, *Mutual Chemical Co. of America*, Baltimore, Md., *Industrial & Eng. Chem.*, **38**, 369-75 (1946) Apr.

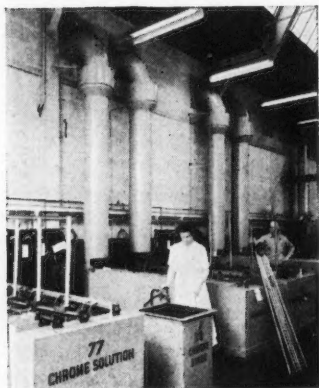
Experimental data presented here are consistent with a dual theory for the mechanism of passivation. The nature of the time functions appears to preclude a simpler mechanism, but the possibility of a more complex mechanism is not excluded.

Fundamental data show that, when chromate is used to inhibit corrosion in water systems under the conditions specified: (a) rate of consumption of chromate is relatively high at first, but rapidly falls off until it is stabilized within one to three months; (b), consumption of chromate is highest at a concentration of about 50 ppm. chromate and lowest at about 500 ppm.; (c), there is little difference, after conditions have been maintained for three months, with chromate concentrations from 250 to 1000 ppm.; (d), as the chloride content of the water is increased, the consumption of chromate increases, especially during the first 10 days while the protective film is forming; (e), rate of con-

sumption of chromate fluctuates in a cyclic manner, but the amplitude and frequency decreases with lapse of time until conditions are substantially constant. These data have important practical applications. They show that it is most advantageous to start treatment of a water system with a comparatively high concentration of chromate, and to maintain such a concentration until the protective film is formed. This concentration may be lowered later. An example illustrates how the optimum concentration of chromate may be estimated for inhibiting corrosion in recirculating water systems, such as are commonly employed for air conditioning and other cooling purposes.

## Looking for a Stopper

## to Corrosion Costs?



One of the largest plating operators in the U.S. chose Amercoat #33 as a "stopper." This corrosion resistant coating for plating equipment is unaffected by spillage and fumes from all types of plating, pickling and rinsing solutions—acids, alkalis, salts. Amercoat #33 is especially designed as a coating for the exterior of plating and rinse tanks . . . fume ducts . . . ventilators . . . piping . . . blowers . . . structural steel. It is an ideal coating for brick or concrete floors, walls and drains, protecting the surface against acid and alkali attack. Write for details and names of users.

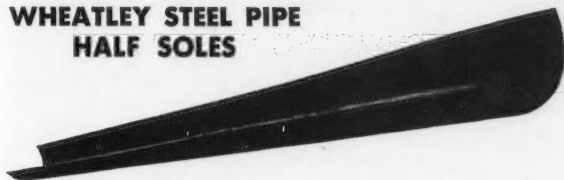
**FOR CORROSION  
CONTROL IT'S**

**Ask for  
Booklet 2-1**



Typical Amercoat installation—71 tanks and all piping and fume ducts were coated. Coating is in excellent condition after two years service.

**AMERCOAT DIVISION:  
AMERICAN PIPE & CONSTRUCTION CO.**  
P.O. Box 3428, Terminal Annex, Los Angeles 54, Calif.

**WHEATLEY STEEL PIPE  
HALF SOLES**

All Edges Straight or Beveled for Welding

**WHEATLEY  
PRESSED STEEL  
COLLAR WRAPS**

I.D., Inches	Wall, In.	Wt./Ft., Lbs.
4 1/4	☆	6.76
6 3/4	☆	12.11
8 3/4	☆	15.57
10 3/4	☆	19.24
12 3/4	☆	22.77

All sizes carried in our Houston and Galveston stock.  
Can be furnished in any length up to 10 feet.

**TOM WHEATLEY CO.***Oil Field Supplies***HOUSTON, TEXAS**

1720 Louisiana  
P. O. Box 2094

Charter 4-4656  
L. D. 785

I.D., Ins.	Thick- ness, In.	Wt./Pr. Lbs.
4 1/4	☆	22
6 3/4	☆	33
8 3/4	☆	42
10 3/4	☆	52
12 3/4	☆	63

☆ Edges Straight or Bevel-  
ed for Welding  
Made in Dresser or Welded  
Joint and for any special  
Type Wrap

**BITUMASTIC COATINGS AND CAREY FELT***plus Cathodic Protection*

insure economical, lasting protection for under-  
ground structures.

Because of their high resistance to temperature  
changes and moisture absorption these materials  
keep costs of cathodic protection at a minimum.

DISTRIBUTED IN TEXAS AND LOUISIANA BY

**BITUMASTIC**

HOT APPLIED PIPE LINE COATING  
COLD APPLIED COATING AND PAINTS

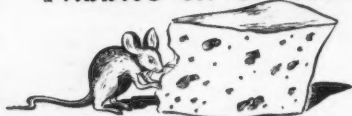
*Carey*

ASBESTOS PIPE LINE FELT

*James E. MAJOR*

514 M & M Building Capital 2203  
Houston 2, Texas

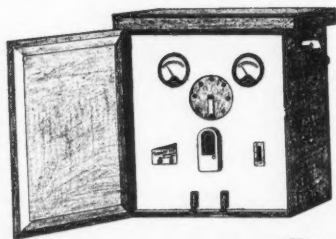
## *As a Mouse Nibbles on Cheese-*



### **So Is Cathodic Corrosion Nibbling On Your Pipe Lines**

As you know the industry is suffering a six billion corrosion loss yearly. A small investment in Good-All rectifiers can add as much as 50 years to your pipe lines.

- ★ Prompt delivery.
- ★ Available in single or 3 phase operation.
- ★ Available in all DC voltages and current output.
- ★ Selenium stacks — heavy duty — coated — high ambient temperature.
- ★ Each stack individually protected by accurately set thermal switch.
- ★ Oversize transformers — highest grade silicon steel core plus fibre glass insulated windings.
- ★ Transformers vacuum impregnated against humidity.
- ★ Entire unit governed by thermal switch.
- ★ Entire unit built in rack—easily removable for periodic inspection.
- ★ All units with ammeter and voltmeter.
- ★ Quick-change tap switches on panel.
- ★ Solderless DC terminals for quick—easier—permanent connection.
- ★ Complete unit and case weatherproof and bug proof.
- ★ High efficiency—low maintenance.



Send for our corrosion bulletin.  
Let us quote you on your requirements.

**CATHODIC  
PROTECTION RECTIFIER**



## **Index to Advertisers**

Allied Chemical & Dye Corp., Barrett Div.....	Inside Front Cover
American Brass Co.....	9
American Pipe & Construction Co.....	44
General Electric Co.....	10
General Paint Corp., Hill-Hubbell & Co. Div.....	Inside Back Cover
Good-All Electric Mfg. Co.....	46
Haering, D. W. & Co., Inc.....	4
Johns-Manville .....	8
Mavor, James E.....	45
Mayes Brothers, Inc.....	5
Owens-Corning Fiberglas Corp.....	7
Stearns, D. E.....	Outside Back Cover
Wailes Dove-Hermiston Corp.....	6
Wheatley, Tom, Co.....	45

## *Control of Pipe Line Corrosion*

### **A Manual**

By O. C. MUDD  
Chief Corrosion Engineer  
Shell Pipe Line Corp.

Now Available in  
Book Form

Single copy, postpaid ..... \$1.25  
5 or more to one address,  
postpaid, at \$1.00 per copy.

#### **Address:**

Book Department, N.A.C.E.  
905 Southern Standard Bldg.,  
Houston 2, Texas.

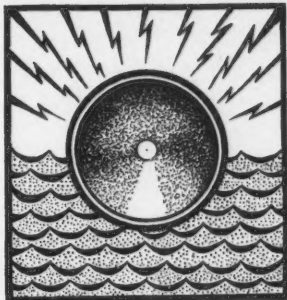
# CORROSION

## *Stopped Cold*

*with*

## HILL, HUBBELL

## *EXTERIOR pipe protection*



HILL, HUBBELL factory applied steel pipe protection is our answer to your pipe corrosion problem.

There are four important factors for the year after year service our protection gives—1 Indoor automatic temperature and climatic control of coating and wrapping pipe—2 Correct enamel heating with filler suspension under agitation—3 Brief duration of enamel heating for fast application—4 Simultaneous application of first and second coats, asbestos felt wrapper and third coat perfectly bonded over mechanically cleaned and primed pipe.



Your investment risk is less when you buy HILL, HUBBELL pipe protection.

### *Hill, Hubbell*



### *Company*

Division of

GENERAL PAINT

CORPORATION

3091 MAYFIELD RD.

CLEVELAND, OHIO.

# **ELECTRICAL INSPECTION**

of insulating materials in place

**One Product—One Service**



**D. E. STEARNS**  
SERRVPORT, LOUISIANA

BETTER COATINGS CONSERVE STEEL